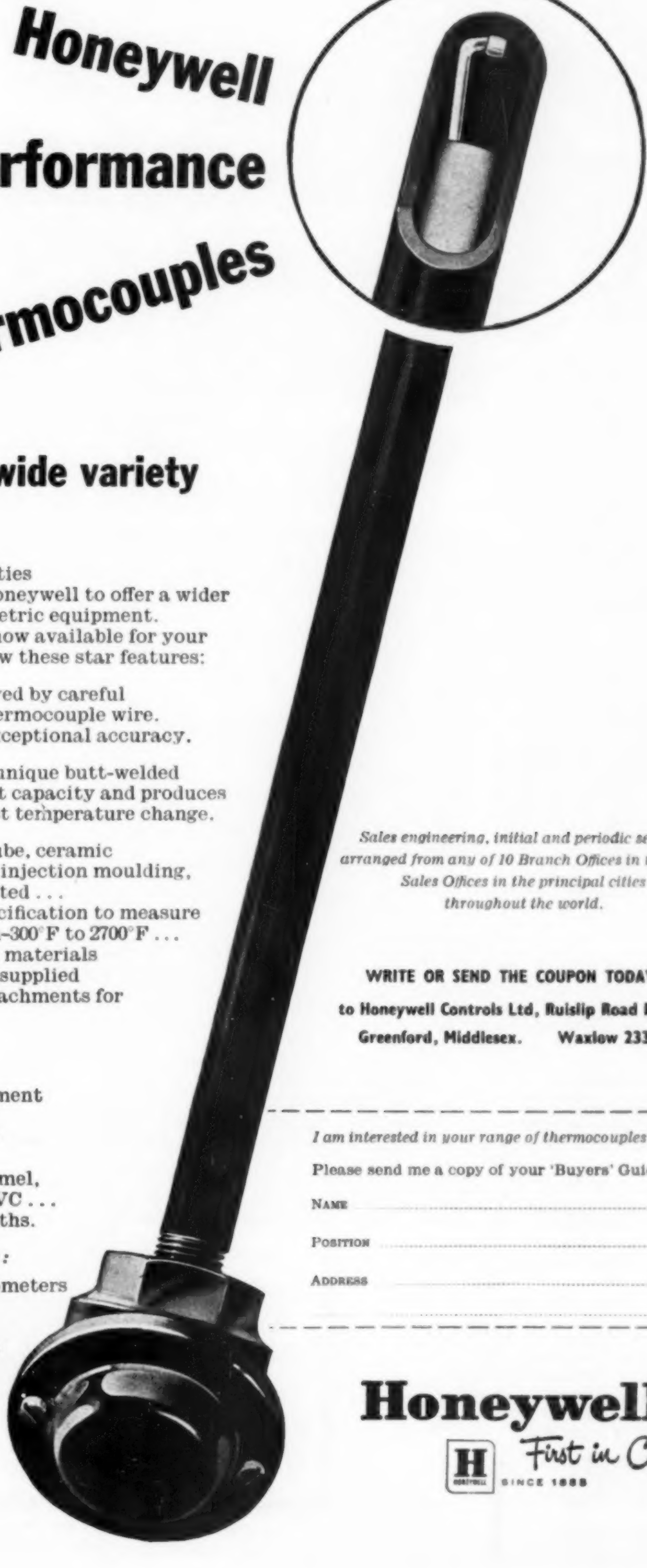
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 62 No. 370 AUGUST, 1960 Monthly: Two Shillings and Sixpence

Honeywell top performance thermocouples



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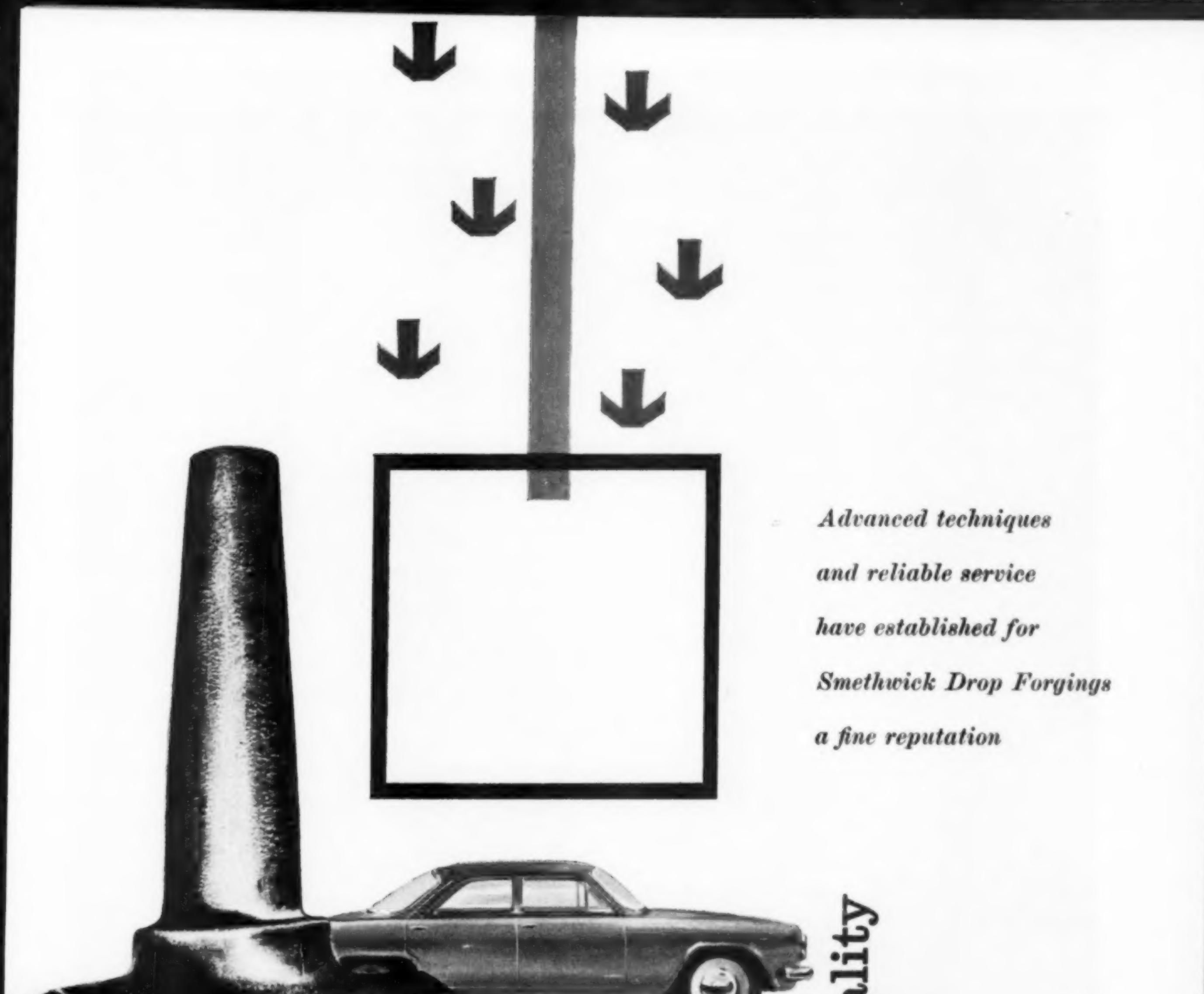

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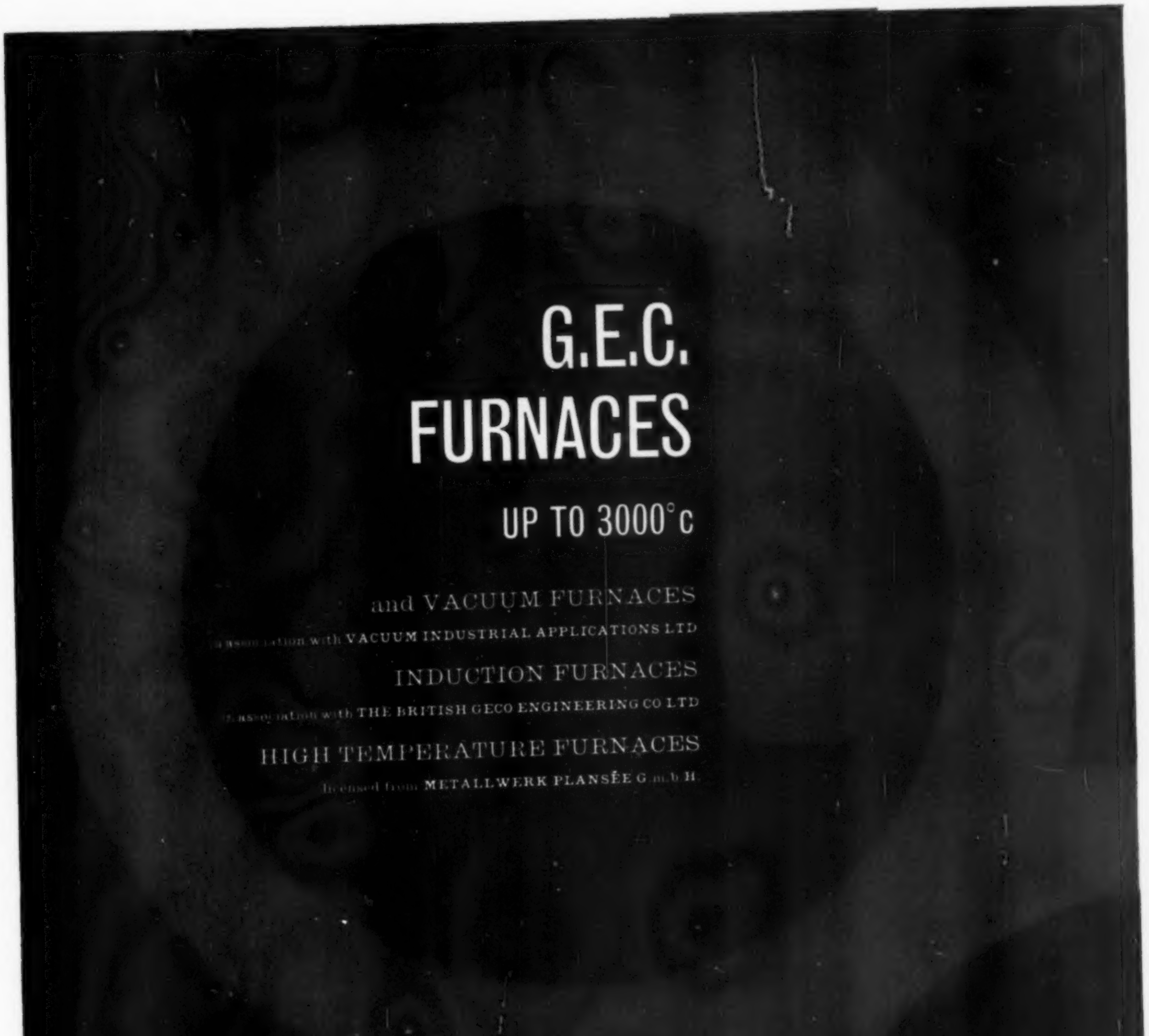
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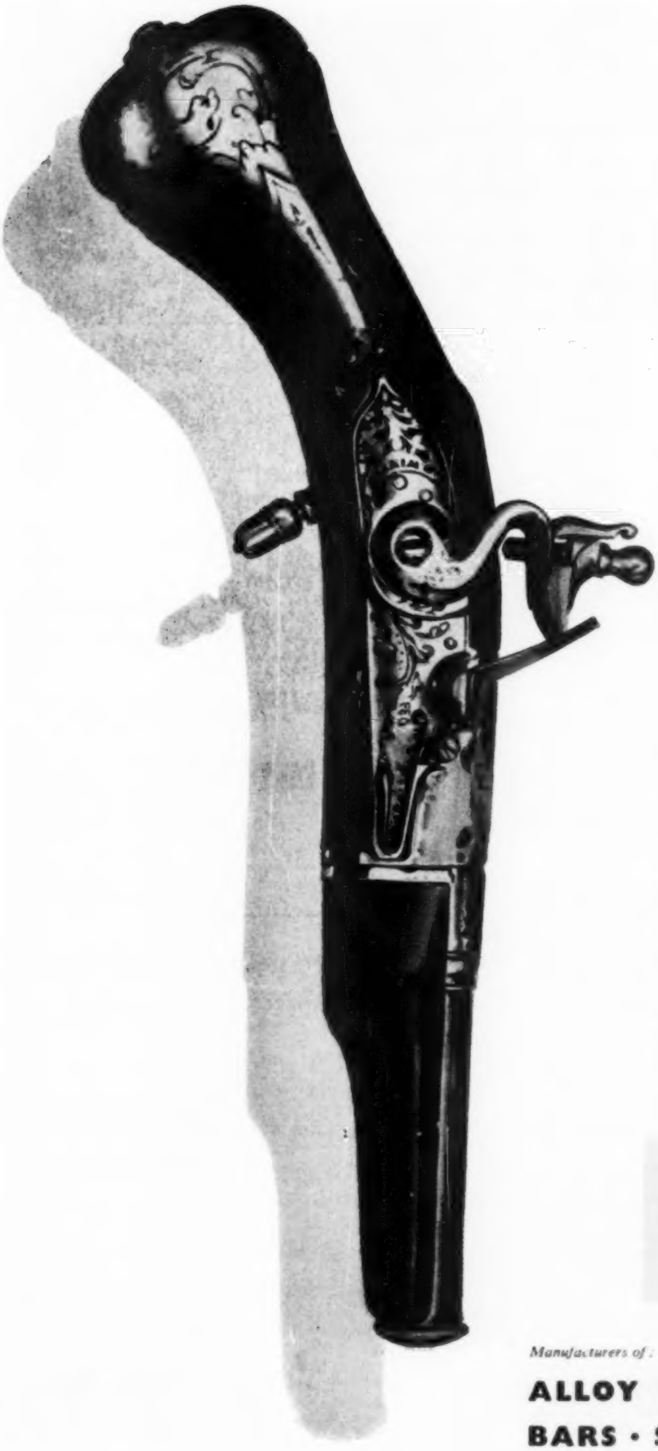

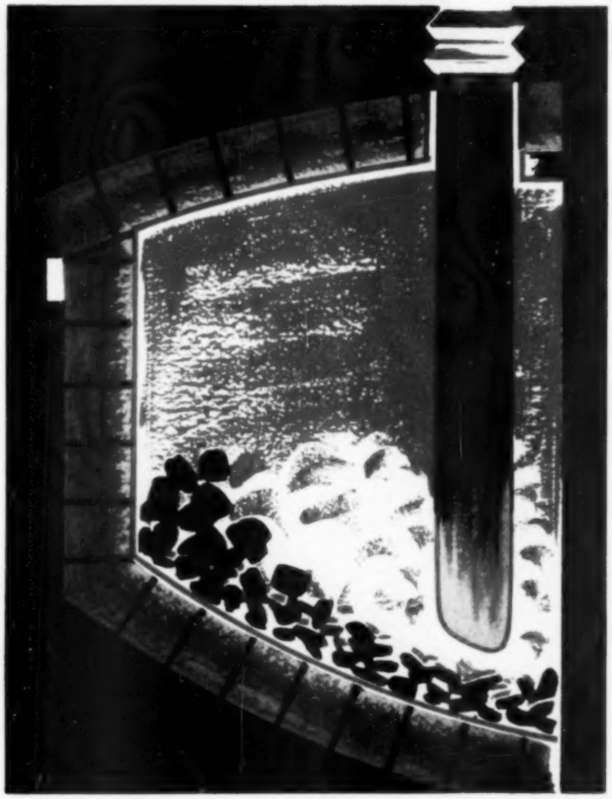

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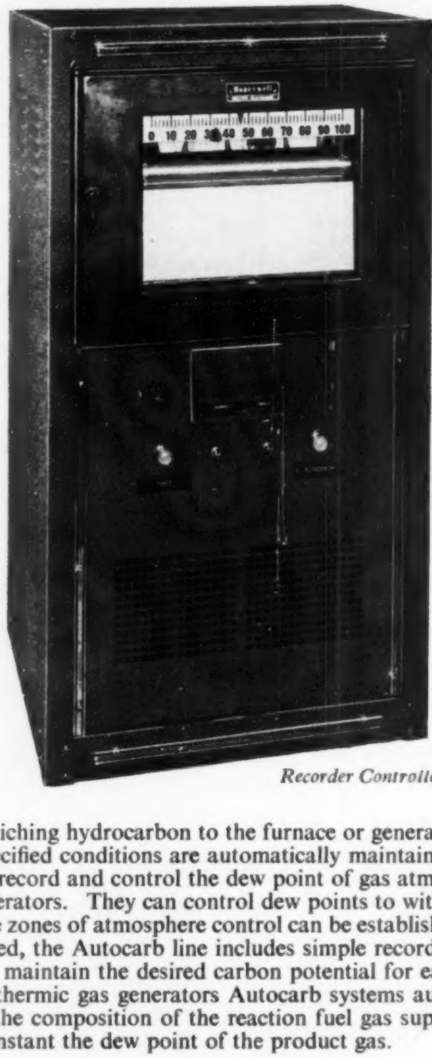
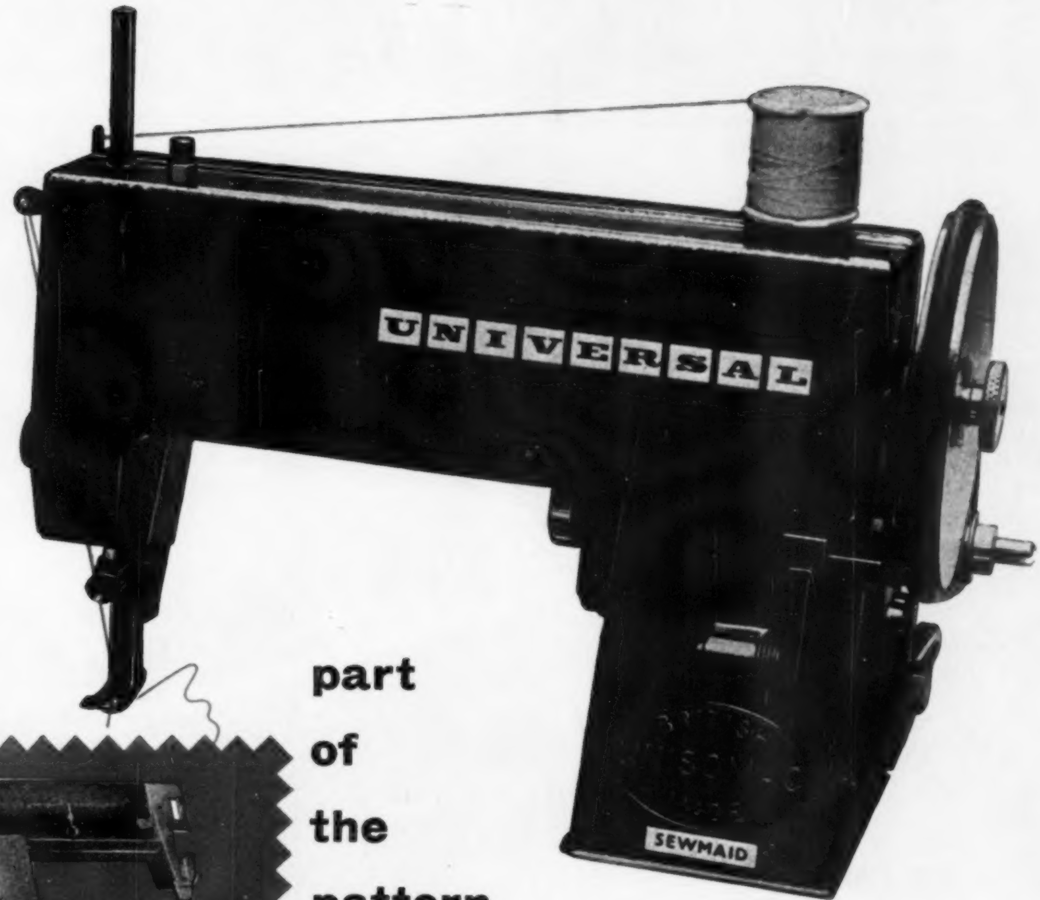
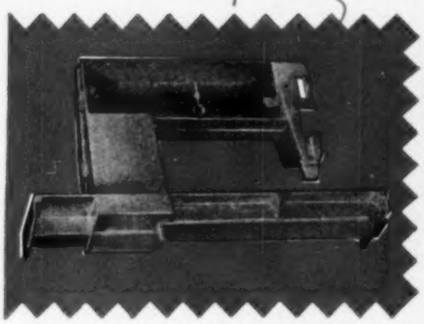


Recorder Controller



part of the pattern



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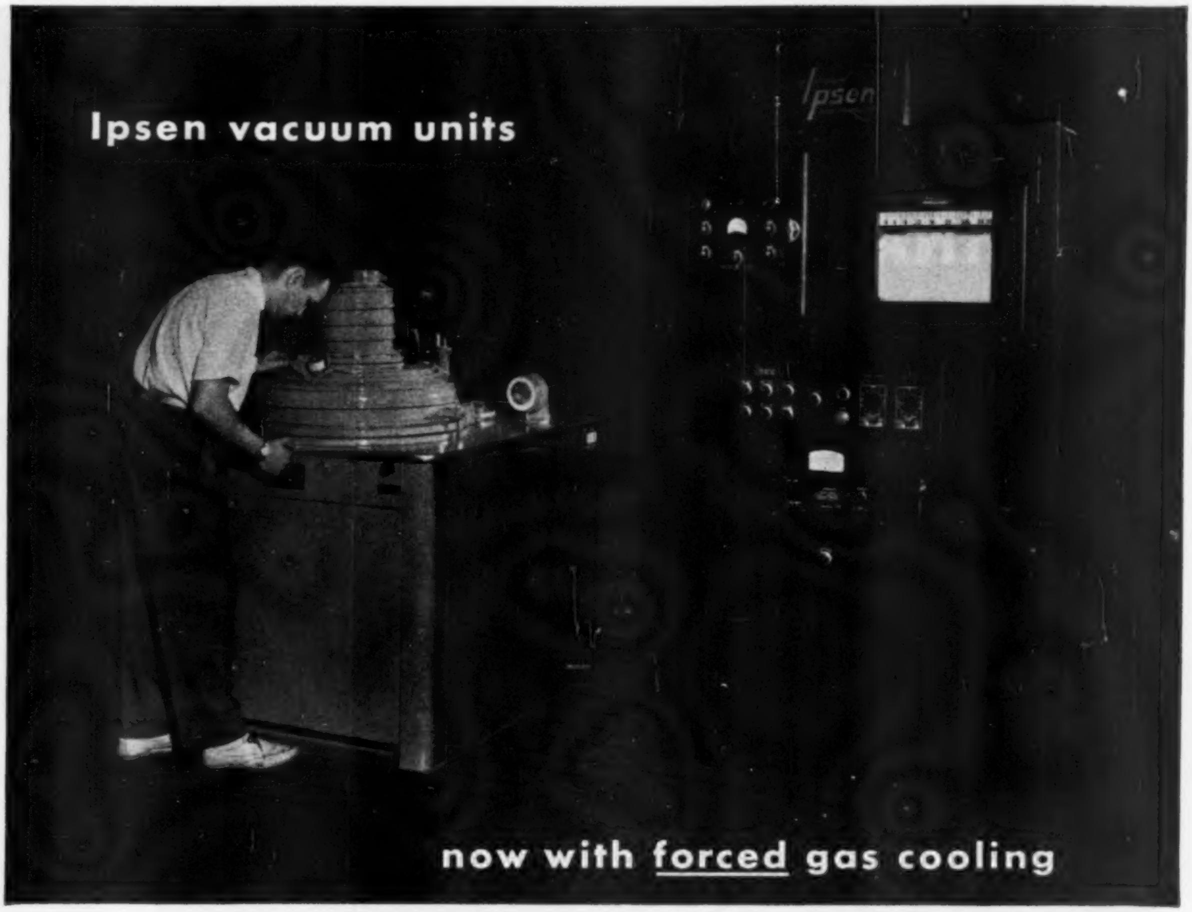

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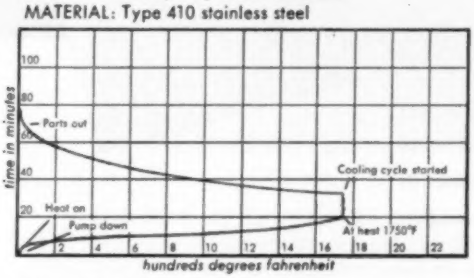
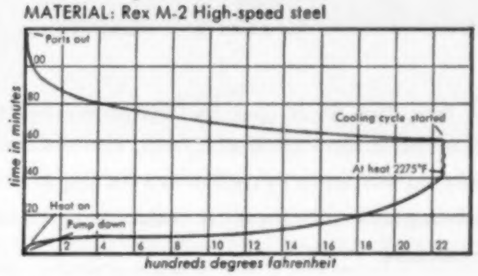
MATERIAL: Type 410 stainless steel



COMPLETE TIME CYCLE: 1 hour 8 min.
RESULTS: Rockwell C 42-43
APPEARANCE: Exceptionally bright

PARTS: Boring bars
MATERIAL: Rex M-2 High-speed steel



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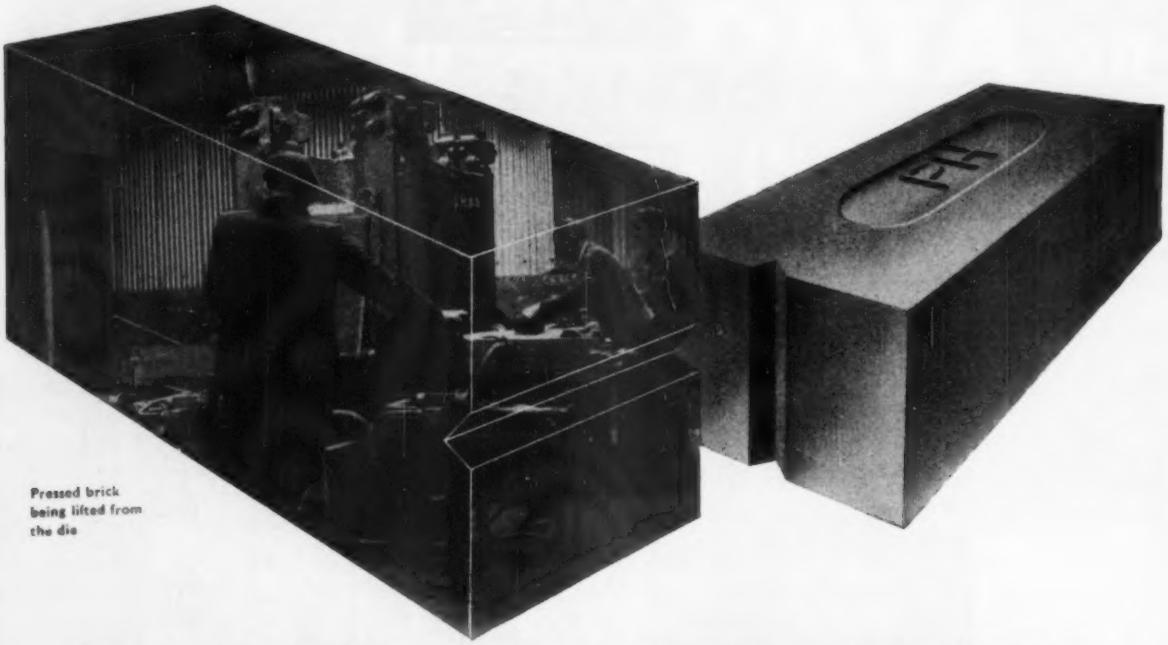

Pressed brick being lifted from the die

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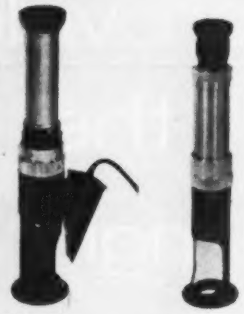
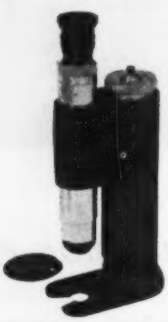
BRL 1.

L. 9a. L. 9b. M. 4



M. 4 E M. 40



BRM 40 BRM 120

VM 30 VM 60

BRL 1	*Pocket Microscope*	Magnification × 6	
	Field of vision	15 m/m	
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	Built-in Battery Illumination.		
L.9a	Magnification	× 16	
	Field of vision	6 m/m	
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L.9b	Magnification	× 16	lamp illumination
	Field of vision	6 m/m	as shown.
	Scale Divisions	0·05 m/m	
M.4	Two Magnifications (by sliding tube)	× 20 in retracted position × 40 in extended position	
	Field of vision	retracted 5·0 m/m, extended 2·5 m/m	
	Scale Divisions	0·1 m/m–0·05 m/m Can be fitted with lamp illumination as shown at M.4.E.	
M.40	Magnification	× 40	
	Field of vision	4 m/m	
	Scale Divisions	0·02 m/m	
	The measuring scale can be rotated to facilitate measuring in different directions.		
BRM 40	Field of vision	4 m/m	
	Magnification	× 40	
	Scale Divisions	0·02 m/m	
BRM 120	Magnification	× 120	
	Field of vision	1·0 m/m	
	Scale Divisions	0·005 m/m	
	Built in Battery illumination.		
	SLIDE MOUNTED FOR PRECISION MEASURING.		
VM 30	Magnification	× 30	
	Measuring range	0–20 m/m	
	Field of vision	3·6 m/m	
	Scale Divisions	0·001 m/m	
VM 60	Magnification	× 60	
	Measuring range	0–20 m/m	
	Field of vision	1·8 m/m	
	Scale Divisions	0·001 m/m	
	The Microscope tube, with cross hair eye-piece is mounted on a slide which is moved laterally by means of a measuring spindle to scan diameter or diagonal of impression. Readings of 0·001 m/m can be made by the vernier scale.		

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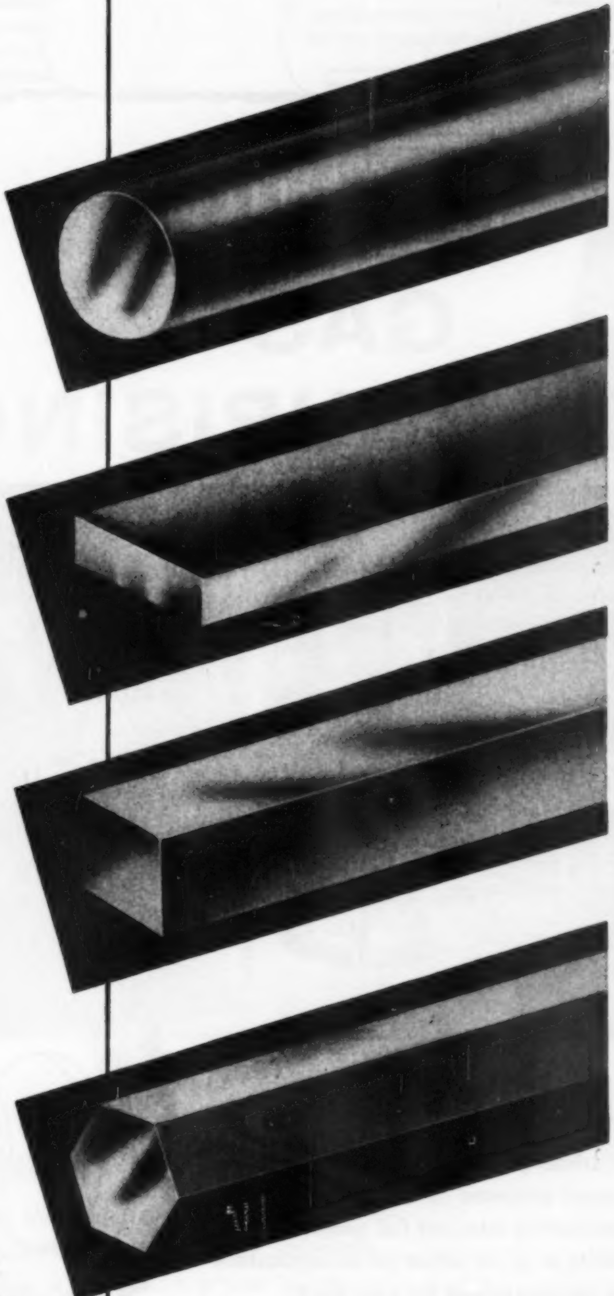

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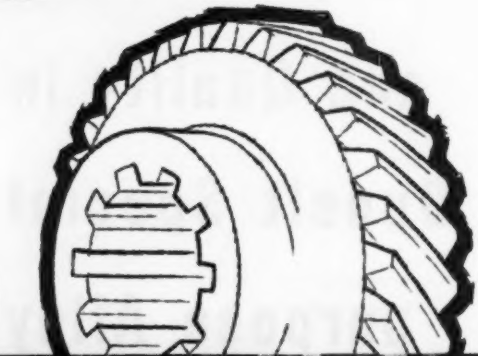

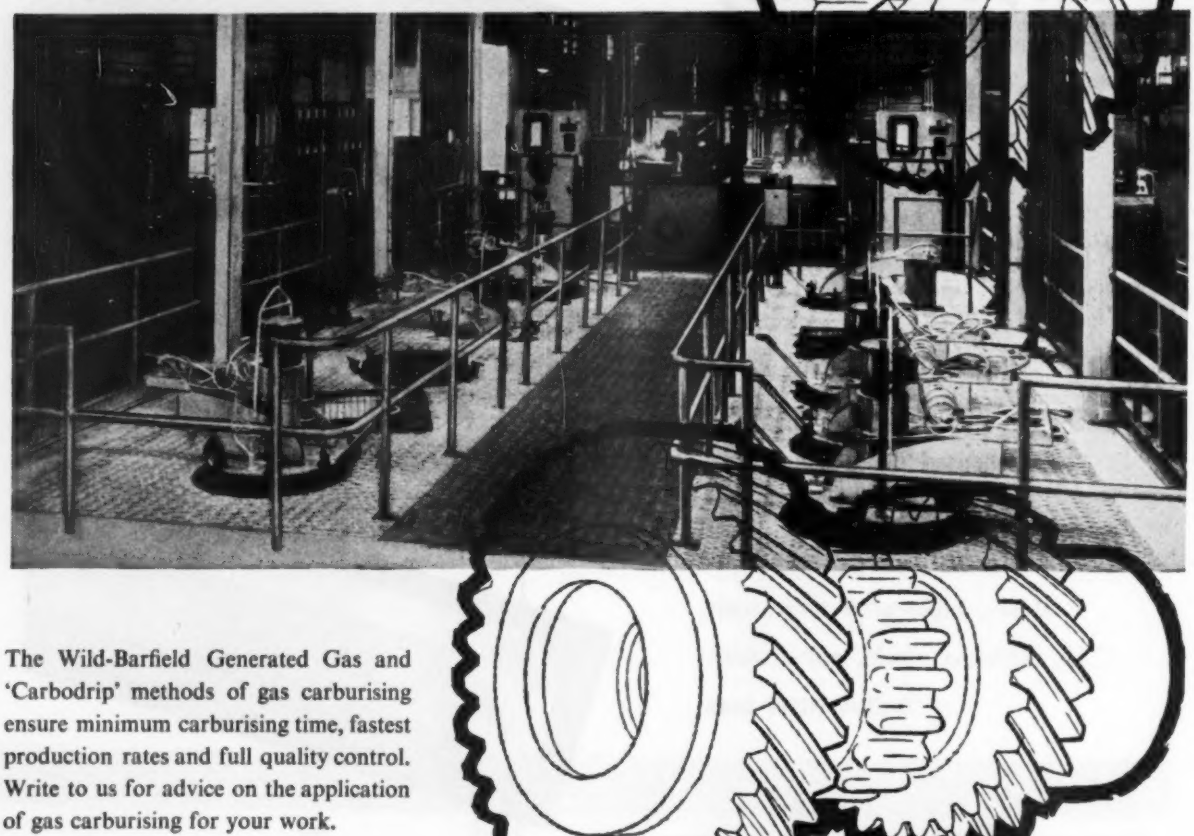

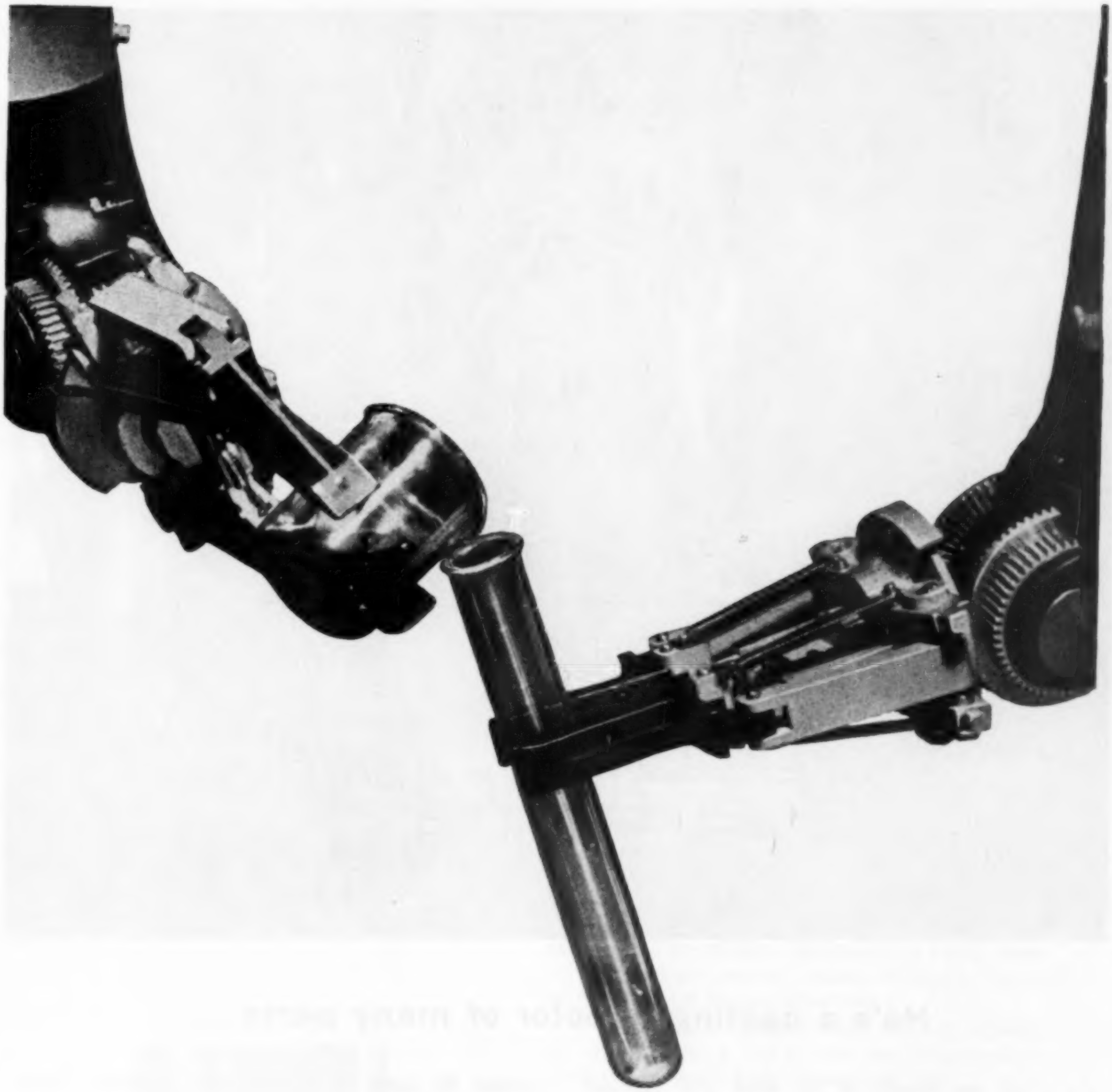

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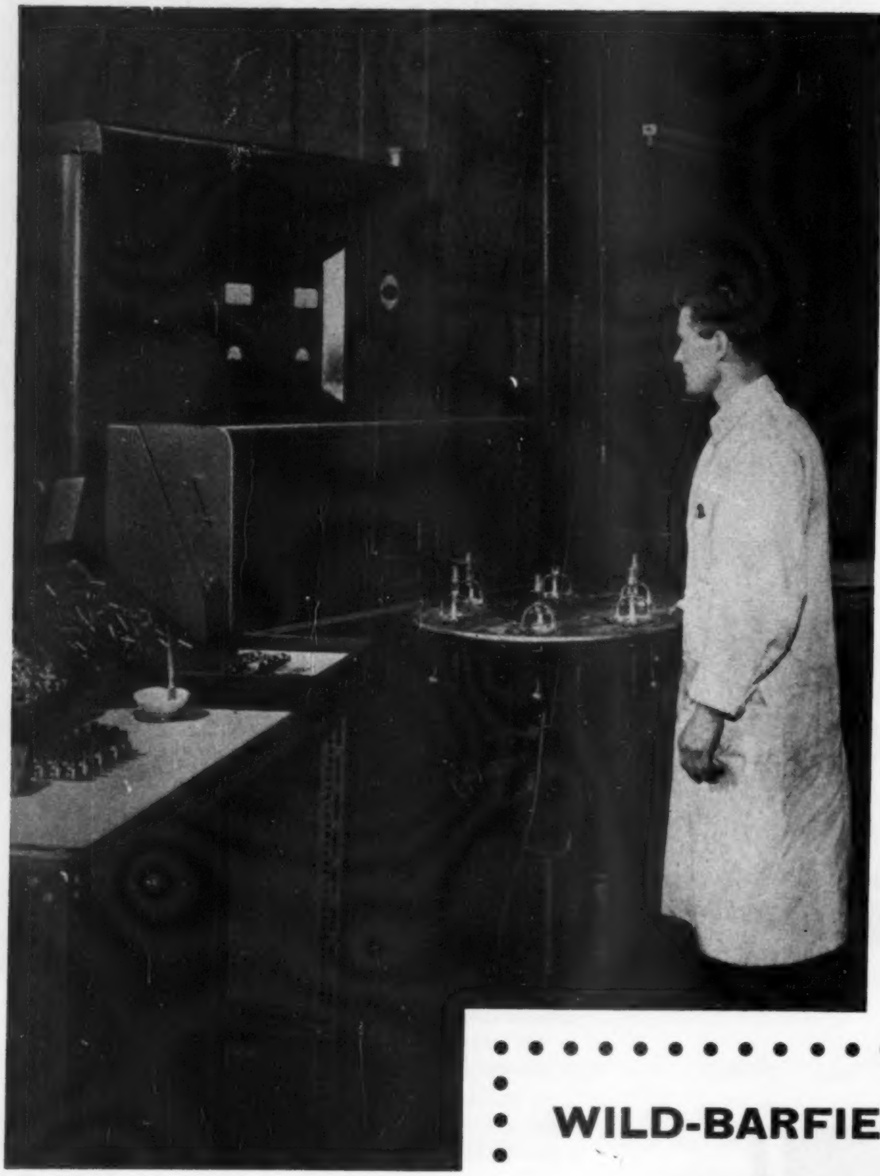

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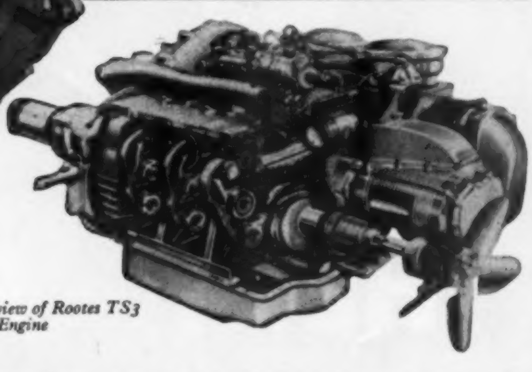

Cut-away view of Rootes TS3 Multi-fuel Engine

Superchargers are widely used in oil engines for pressure charging and scavenging and are essential in the opposed piston type. One of the best known designs is the 'Roots-type' supercharger, made in this country by Wade Engineering Ltd., Brighton.

Quiet operation and maximum overall efficiency are required and a well-designed single helical pair of gears meets these requirements. The driving gear which meshes with a bronze wheel is made from En24V steel and the drive shaft, which has a serrated bore, from En100.

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$1\frac{1}{8}$ in. dia.	Oil quenched 850°C tempered 510°C	79	83	15	28
$1\frac{1}{8}$ in. dia.	Oil quenched 850°C tempered 560°C	68	73	19	55
$2\frac{1}{2}$ in. dia.	Oil quenched 840°C tempered 650°C	57	64	20	65
$5\frac{1}{4}$ in. dia.	Oil quenched 830°C tempered 650°C	50	58	19	75

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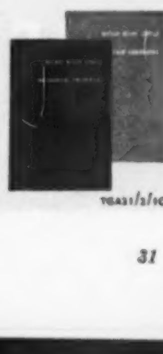

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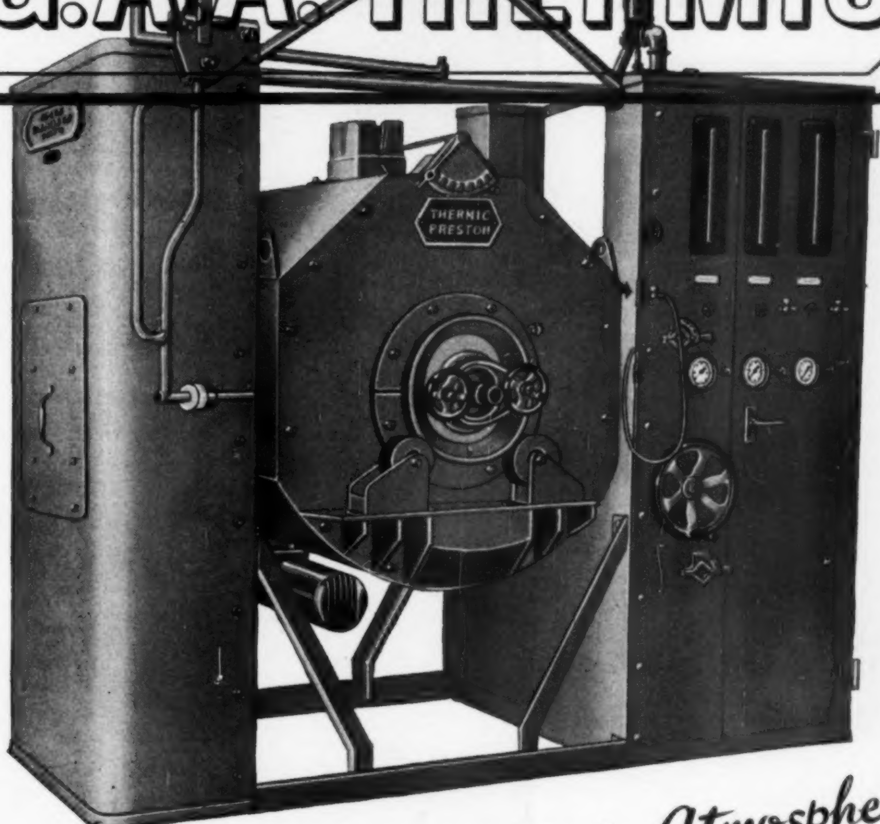

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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LABORATORY METHODS SUPPLEMENT

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE "METALLURGICAL ENGINEER"

AUGUST, 1960 Vol. LXII. No. 370

Three Hundred Years

OUR ideas of time are relative. The period which has elapsed since the first issue of this journal appeared in November, 1929, is almost half the allotted span of three-score years and ten, and has seen the introduction of a large number of new scientific and technical periodicals. Some of these have fallen by the wayside, but the majority are still active, and in comparison we are an "old" journal. On the other hand, the *Engineer* celebrated its centenary a few years ago, and there are many other old-established journals relative to which we are young. Almost all of these, however, are mere infants in comparison with the *Philosophical Transactions of the Royal Society of London*, in which are published memoirs of scientific investigations communicated by Fellows of the Society, and which has appeared continuously since 1665. This was the Society's only publication until 1832, when the *Proceedings of the Royal Society* was introduced. This consists of shorter papers and is issued at frequent intervals. It first made its appearance as a collection of abstracts of papers published earlier in the *Transactions*, but by the third volume abstracts were included of papers which had not appeared in the *Transactions*. In the seventh volume (1854–5) original papers considered less important than those in the *Transactions* were printed in full. Gradually the importance and length of the original papers increased and the abstracts disappeared. By 1905 the number of papers accepted for publication in the *Proceedings* had increased to such an extent that it was decided to follow the procedure adopted for the *Transactions* in 1887 and divide them into two series: A—mathematical and physical contributions; and B—contributions of a biological nature. Since its inception, papers by some of the most outstanding scientists of their time have been printed in the pages of the *Proceedings*, and today the greater part of the scientific papers published by the Royal Society appear in it.

The *Philosophical Transactions* is the senior scientific journal in the world, which is not altogether surprising, as the Royal Society is the oldest scientific society of any kind which has enjoyed continuous existence, the original Italian Accademia del Cimento, which was founded a few years before the formal inception of the Royal Society, being short-lived. In the mid-seventeenth century, it was widely held that the writings of the great classical philosophers were the one fountain of wisdom, and that the writings of Aristotle were the great authority on all scientific matters, such as the laws of terrestrial mechanics, the motions of the heavens, and the nature of light and colour. Not all subscribed to this view, and in the 1640's a number of men who believed that systematic observation and experiment provided the best means of investigating natural happenings began to meet in London, and later in Oxford also. After certain vicissitudes the London and Oxford groups, reinforced by men of similar views and interests, came together again in 1659 at Gresham College in London, and on the return of Charles II to the throne in 1660 the meetings became more regular. At a historic gathering on 28th November, 1660—attended by Lord Brouncker, Mr. Boyle, Mr. Bruce, Sir Robert Moray, Sir Paul Neile, Dr. Wilkins, Dr. Goddard, Dr. Petty, Mr. Ball, Mr. Rooke, Mr. Wren, and Mr. Hill—the idea for the formation of a society for promoting physico-mathematical experimental learning was propounded. A list of forty names was drawn up and a subscription of a shilling a week fixed. A week later they were informed that the King approved of the proposal, and within eighteen months the new society received a royal charter of incorporation, in which it was named *Regalis Societas*—Royal Society. Shortly afterwards the King presented the Society with a mace and a book containing the charter and statutes, both of which are in regular use today. All Fellows formally admitted to the Society sign the book, as did the founder, King Charles II, and as did Isaac Newton, Robert Boyle, Christopher Wren and all the great British men of science since 1660.

The reception accorded the new Society was, to say the least, mixed. Names like Christopher Wren, John Evelyn, Samuel Pepys and John Dryden bear witness to the width of its appeal. Nor was the sympathy of the literary world lacking. Moreover, the patronage accorded to the Royal Society by established authority was neither purely formal nor mere lip service. Prince Rupert made communications on his own account, and the Earl of Sandwich, sent to escort Catherine of Braganza from Portugal, allowed himself to be set the task of making observations for the Royal Society on the tides and on the saltness of the sea. The King himself was on terms of friendly intimacy with many of the members, often visiting with Sir Robert Moray the laboratory established in Whitehall. On the other hand, the Public Orator of the University of Oxford declaimed against the Royal Society in a theatre built by Wren, and Antony Wood declared it to be an obnoxious body. Attacks were made from the pulpit and the strangest accusations came from other quarters. The complaints openly made were of atheism, impiety and subversion. It was said that it elevated sensual ideals and encouraged great expense of spirit in the pursuit of vain truths, and that it might challenge the authority of the Universities and invade the province of the physicians.

Times have changed since 1660, but universal acknowledgment of the benefits arising from "the promotion of natural knowledge" mentioned in the Society's royal charter is still to come. Although today scientific studies receive extravagant praise, they are also subject to intemperate criticism. As Sir Cyril Hinshelwood, O.M., President of the Society, said in his Tercentary Address: "Every complaint and reproach levelled in

the seventeenth century, every fear expressed, every resentment, interested or disinterested, openly or secretly working, can be paralleled in the recent past. Every anxiety, misgiving, criticism or reserve voiced today has been countered by the seventeenth century apologists. Nor can the threat of destruction by the release of nuclear energy really have aggravated the issue, for the perils of atomic warfare are at least no more terrible than the prospects of eternal damnation to which many in the earlier age believed the new doctrines were leading men."

During the last three hundred years there has been a steady increase in the number of those working to uncover the secrets of nature, regardless of the criticism levelled against them. In so doing, they have lived up to the motto of the Royal Society, *Nullius in Verba*, accepting the authority of none and, on the whole, unmoved by praise or blame. Space will not allow of detailed reference to the results of their labours, but there is no doubt that they have led, particularly during the last hundred years, to a transformation of daily life, and things which in the reign of Charles II would have seemed like " the dreams of visionaries or the impostures of charlatans " as Sir Cyril put it, are now part of the common scene. In the realm of ideas, too, the development has been dramatic, particularly where discoveries have seemingly contradicted established religious and moral beliefs. Instances of this may be found in the refutation of the literal truth of Genesis by the time scales revealed by geology and biology, and the doubt cast on the special creation of man by the theory of evolution. Nevertheless, men of science have numbered about the same proportion of religious believers as the population as a whole : nor have they been conspicuously less well endowed with kindness or morality.

At its inception, the reigning monarch was the Patron of the Royal Society, and Her Majesty The Queen is the thirteenth monarch to continue this tradition. It was fitting, therefore, that she should open the Tercentenary Celebrations at a colourful and impressive ceremony at the Royal Albert Hall last month. As the procession of Fellows clad in their scarlet academic robes slowly wended its way down the length of the hall, followed by processions of Foreign Members and official representatives of national academies of science, universities and international scientific organisations, one pondered on the changes which might take place in the next three hundred years, for while the Royal Society has a glorious past, it also has a future—a future linked with the progress of science as a whole. Does the rapidly increasing number of workers in the scientific field mean that progress will proceed at an accelerating rate, or are we approaching the peak—or at least a plateau ?

Reference has already been made to the Tercentenary Address delivered by the President of the Royal Society, after the formal opening of the celebrations by Her Majesty. Sir Cyril concluded his consideration of the future with these words : " This commemoration is for us a great event in our history. The future is unknown. The chronicles record the actions and the thoughts of men, and if, as well may be believed, thought is a creative process, then the future is more than deeply hidden : it is uncreated. The golden promises offered by the release of nuclear energy, by the exploitation of outer space, by the discoveries of genetic mechanisms, may in one way or another be redeemed, but the best are yet unspoken. A great upheaval of ideas may come with a complete re-orientation of science in its relation to philosophy and to the conception of possible worlds. But we know neither the day nor the hour.

" It is the duty of the Royal Society not to predict, not to legislate, but to maintain within the larger community the smaller one in which creative activity can flourish. Its members owe a multiplicity of loyalties, none of which can be fulfilled without the others : to mankind in general, to their native land, and to the Royal Society itself. But that is not all, for there are communities in time as well as space. The most original minds, in some sense isolated in all contemporary groupings, find their true affinities in continuing the sequence of their predecessors, and their fulfilment only in their successors. In a measure this is true not only of genius but of all men. It is what moves us in history. It is what the honouring of this occasion means."

Personal News

Mr. S. N. Kinsley, deputy secretary of the research and development department of The United Steel Cos., Ltd., has succeeded Mr. Geo. H. Davison as secretary of the department on the latter's retirement. Mr. Davison, who has been with the company for 27 years, will continue to serve in a full-time advisory capacity for the time being.

The Committee representing the Royal Society and the Armourers and Brasiers' Company has appointed Dr. J. H. Brunton, of the Laboratory for the Physics and Chemistry of Solids, Cavendish Laboratory, Cambridge, to the Armourers and Brasiers' Research Fellowship from October 1st, 1960, to work on deformation characteristics of base metals at very high rates of strain at the Laboratory for the Physics and Chemistry of Solids, Cavendish Laboratory, Cambridge.

Mr. W. E. A. Redfearn has resigned as chairman of the Alloy Steels Association and is succeeded by Mr. R. Bavister. Mr. Redfearn who is a director of English Steel Corporation, Ltd., and managing director of one of its subsidiaries and a director of another, has been chairman of the Alloy Steels Association for ten years. Mr. Bavister is a director and commercial manager of Samuel Fox and Co., Ltd.

At a recent meeting of the council of the British Welding Research Association, Mr. J. D. D. Morgan and Dr. L. M. Wyatt were appointed to the research board. Mr. Morgan is with the General Chemical Division of Imperial Chemical Industries, Ltd., and is the chairman of the I.C.I. Welding Panel. Dr. Wyatt is the chief metallurgist of the Central Electricity Generating Board.

Richard Hill, Ltd., of Middlesbrough, a member of the Firth Cleveland group, have appointed Mr. J. E. Lennard as general sales manager. Mr. Lennard will be based for the present at Byron House, 7/9, St. James' Street, London, S.W.1.

A Thermal Cracking Test for Steels and Alloys

By M. Riddihough, M.Met., A.R.I.C., F.I.M.

A thermal cracking test has been developed for comparing metals by quenching from 650° C. upwards, in which a small cylindrical specimen is heated by an oxy-acetylene flame and water quenched. Results of thermal cycling and subsequent hardness testing and microscopic examination are given for some steels, cast iron, and hardfacing and heat resistant alloys.

A CONSIDERABLE proportion of heat resisting tools and components used in industry fail eventually through cracking brought about by thermal fluctuations. Typical examples are permanent moulds for metal castings, hot extrusion dies, and hot forging and shearing tools. Most of the published work on the subject of thermal cracking appears to have been sponsored by aircraft companies interested in gas turbine blades, and the majority of tests were carried out on sharp edges. This introduces a strong geometric factor which has little bearing on industrial practice and, in contrast, the test procedure now described was designed to cause thermal cracking of a test piece with a minimum of geometrical stress raisers, in an endeavour to obtain comparative results indicative of the physical properties of alloys. Results obtained on the test are reproducible to ± 10%, and as the test bars are simple to make and a batch can be tested in a few hours, a number of industrial alloys have been tested at temperatures up to 950° C.

Description of Rig

The specimen (Fig. 1) is ½ in. diameter, is ground all over, and has an annular vee groove : the test is carried out on the end faces. The test rig is illustrated in Figs. 2 and 3, from which it will be seen that the specimen is raised on a plunger so that its end face dwells in an oxy-acetylene flame. The heating cycle is a constant period of 8¾ seconds, derived from a cam driven by a geared synchronous motor, and the temperature to which the specimen is heated is controlled by the fuel gas supply. The torch is a high pressure welding model with the tip having an orifice 0·050 in. in diameter. Oxygen is supplied through a two-stage pressure reduction valve from a 250 cu. ft. capacity cylinder, and the acetylene supply is from a 250 cu. ft. cylinder similarly controlled. The torch taps are fully open and the gas pressure is controlled by needle valves, the pressure being checked by sensitive pressure gauges.

The oxy-acetylene flame is adjusted until a white excess acetylene flare just begins to appear. This is a sensitive indication of flame conditions and assists in controlling the temperature of the specimen, as slight variations in pressure of the oxygen or acetylene alter this visible indication. At an operating temperature of 650° C., the point of the white inner cone of the flame is 0·22 in. from the specimen test face, and at 950° C. it is 0·12 in. away.

The temperature reached by the end face of the specimen just before quenching is measured by an optical pyrometer sited so that it views the test face as it is lowered from the flame into the water bath, which is kept at a constant temperature by pump circulation from a 30 gallon capacity tank.

When the specimen is lowered into the water bath, it is caught by the hinged projections of the top rails and it rolls down and falls on to the bottom rails and is finally halted behind other specimens, which are picked up in turn by the plunger. The position of the specimen in relation to the flame is accurately controlled by a vee projection on top of the plunger mating with the annular

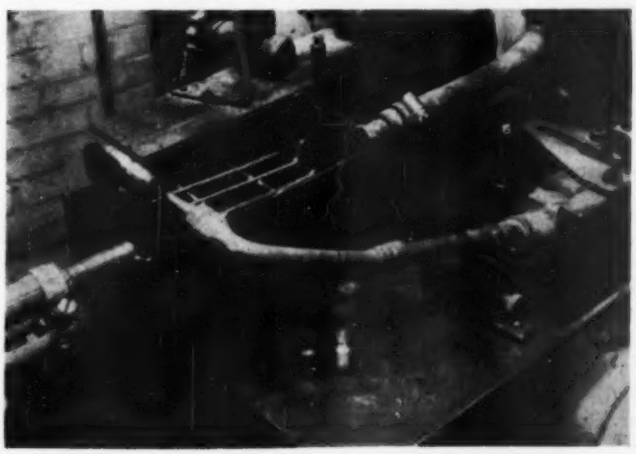


Fig. 2 (right).—Test rig with water quench.

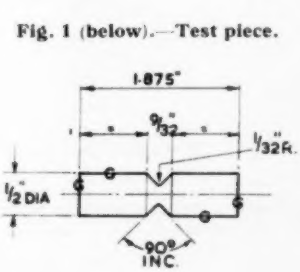


Fig. 1 (below).—Test piece.

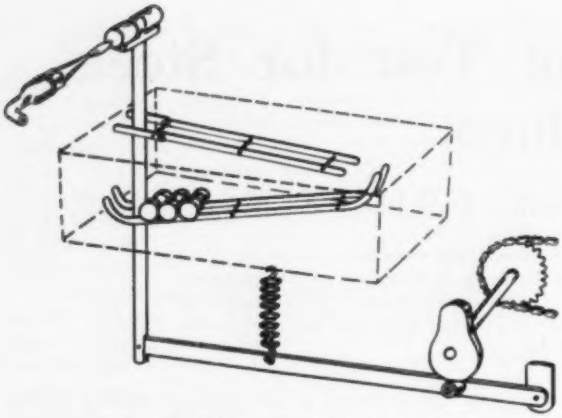


Fig. 3.—Diagrammatic view of test rig.

groove in the specimen, so that the end face of the specimen is always the same distance from the torch nozzle. Up to six specimens are tested in a batch, so that the inclusion of a standard enables a check to be made on operating conditions.

The importance of standardising the rate of cooling was emphasised in early experiments with the rig, when the specimens were cooled by an air blast instead of by water quenching. The air blast (5 lb./sq. in.) was applied by a torch similar to the heating torch. From a temperature of 950° C. approximately 25,000 cycles were required to cause cracking of specimens of cobalt-base alloy 104 with the air blast, whereas using water quenching the number of cycles for cracking the same alloy is 75.

End Point of Test

Cracking commences at the centre of the specimen face and then spreads rapidly over the face in the course of two to ten cycles. Failure is taken as the point when this rapid crack propagation takes place.

Reproducibility

To determine the variation which might be expected in using the rig, 24 sand cast specimens were chosen from the same melt of alloy 104 by checking for soundness by means of X-ray and microscopic examination. The test faces were finally polished on 300 grit emery paper—the standard finish adopted for all tests. The specimens were tested in batches of four and Table I shows that each batch gave consistent results, although there is a variation between batches within ± 10%.

TABLE I.—THERMAL CRACKING RESULTS ON ALLOY 104 TEST BARS

Test	Specification No.	Cycles to Crack from 950° C.
A	A1	80
	2	80
	3	72
	4	76
B	B2	66
	3	69
	4	65
C	C1	72
	2	67
	3	71
	4	73
D	D1	74
	2	78
	3	77
	4	80
E	E1	73
	2	75
	3	75
	4	78

Test Results

Whilst the rig has been used primarily on cobalt-base alloys, results have been obtained on some typical industrial cast irons and steels, and Table II gives their composition and treatment prior to testing. Results of tests are reported in Table III, and for comparison purposes they have been grouped according to their industrial characteristics under the headings of cast irons, steels, hardfacing alloys and gas turbine alloys.

Cast Irons Tested at 650° C. and 950° C.

When the test rig was first put into use some years ago, samples of typical heat resisting cast irons were obtained. Unfortunately, the composition of the samples was not known and the results (1–3)* are therefore quoted with some reserve as a comparison with the pearlitic and ferritic nodular irons. The pearlitic iron (4) has extremely good heat cracking resistance at 650° C., but at 950° C. the ferritic nodular iron (5) is better, and in the ferrous alloys is only excelled by the tungsten hot die steel (13), the austenitic stainless steel (15) and mild steel (8).

Steels Tested at 650° C.

Mild steel has the maximum crack resistance of the steels in the soft condition and is closely followed by the B.S. 224 No. 1 hot die steel. Increasing the hardness of the die steels decreases their crack resistance as shown in Fig. 4, from which it is interesting to see that the higher alloy B.S. 224 No. 5 steel has better properties in the industrially used range for hot die steels, i.e. 400–500 D.P.H. Tungsten hot die steel at 543 D.P.H. is evidently better than the two B.S. steels at the same hardness.

Steels Tested at 950° C.

The non-hardening steels naturally have the better properties at this temperature, in the following order—austenitic stainless steel, mild steel. All other steels

* These numbers refer to the identification numbers in Tables II and III,

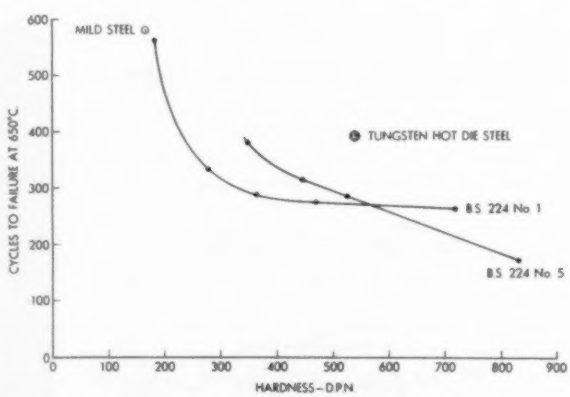


Fig. 4.—Crack resistance v. temperature of some hot die steels.

TABLE II.—COMPOSITION OF BARS TESTED

Identification	Description	Composition (%) C	Si	Mn	Cr	W	Mo	Fe	Ni	Co	Others	Remarks
1	Ni-Cr-Mo cast iron											
2	Meehanite cast iron											
3	Heat resisting cast iron											
4	Pearlitic nodular cast iron	3·14	1·80	0·28	—	—	—	Rem.	0·62	—	Mg ·048	
5	Ferritic nodular cast iron	3·14	2·10	0·34	—	—	—	Rem.	0·62	—	Mg ·045	
6	Martensitic chromium cast iron	3·70	1·0	2·5	21·0	—	—	Rem.	—	—	—	X
7	Austenitic chromium cast iron	2·70	1·0	6·0	29·0	—	—	Rem.	—	—	—	X
8	Mild steel	0·22	0·01	0·96								
9	Non-shrink die steel	0·90		1·70	0·25			Rem.				X
10	B.S. 224 No. 1 hot die steel	0·60	0·30	0·70	—		—	Rem.	—	—		X
11	B.S. 224 No. 5 hot die steel	0·55	0·30	0·65	0·65	—	0·30	Rem.	1·50			X
12	Non-distorting die steel	2·15	0·60	0·30	12·30	—	—	Rem.	—	—		X
13	Tungsten hot die steel	0·30	—	0·30	3·40	8·40	—	Rem.	—	—	V 0·34	X
15	Austenitic stainless steel	0·10	—	—	18·24	—	3·13	Rem.	7·48	—		
16	Stellite 1*	2·48	0·84		32·74	13·31		1·73		Rem.		
17	Stellite 12*	1·79	1·06		28·66	8·72		1·41		Rem.		
18	Stellite 6*	1·12	1·01		26·12	5·11		0·95		Rem.		
19	Deloro C*	0·13	0·51	0·37	17·16	5·23	16·65	6·47	Rem.	—		
20	Deloro C.26*	0·20	0·07	0·14	9·87	—	2·15	0·16	Rem.	—	Al 11·33	
21	Stellite 7*	0·45	0·30	—	24·45	5·17	—	0·86	0·13	Rem.		
22	Stellite 8*	0·13	0·28	—	29·03	—	5·95	0·40	—	Rem.		
23	Stellite 422–19*	0·51	0·11	0·07	25·36	—	6·23	1·50	14·55	Rem.		
24	Stellite X.40*	0·50	0·39	—	25·33	6·79	—	0·40	10·03	Rem.		
25	H.R.C.M.†	0·18	1·52	0·61	22·5	2·04	—	Rem.	11·5	—		
26	G.19‡	0·36	0·92	0·64	20·7	2·44	1·76	—	13·2	9·25	Nb 2·89	
27	G.39‡ (Foundry A)	0·61	1·12	1·07	20·21	2·86	2·73	3·91	Rem.	Nil	Nb 2·94	
28	G.39‡ (Foundry B)	0·58	0·96	1·20	20·0	2·91	1·95	4·4	Rem.	—	Nb 2·47	
29	Nimonic DS§	0·10	2·25	1·0	18	—	—	Rem.	38	—	—	X
30	Nimonic 75§	0·10	<1	<1	19	—	—	<5	Rem.	—	Ti 0·4	X
31	Nimonic 80§	<0·1	<1	<1	20	—	—	<5	Rem.	<2	Ti 2·0, Al 1·0	X
32	Nimonic 90§	<0·1	<1	<1	20	—	—	<5	Rem.	20	Ti 2·5, Al 1·5	X

X Nominal Composition

Trade marks: * Deloro Stellite, Ltd. † Firth-Vickers Stainless Steels, Ltd. ‡ Jessop-Saville, Ltd. § Henry Wiggin and Co., Ltd.

TABLE III.—TEST RESULTS

Identification	Description	Treatment	Cycles to Failure from 650° C.	Cycles to Failure from 950° C.	Hardness (V.P.N.) Before Test	After 650° C.	After 950° C.
Cast Irons							
1	Ni-Cr-Mo cast iron	As cast.	94	—	263	301	—
2	Meehanite cast iron	As cast.	167	—	214	242	—
3	Heat resisting cast iron	As cast.	294	—	191	157	—
4	Pearlitic nodular cast iron	As cast.	421	27	257	257	570
5	Ferritic nodular cast iron	16 hr. at 900° C.; 48 hr. at 690° C.	78	123	138	150	454
6	Martensitic chromium cast iron	As cast.	8	87	661	685	312
7	Austenitic chromium cast iron	As cast.	3		590		
Die and other Steels							
8	Mild Steel	Rolled bar.	580	195	165	191	481
9	Non-shrink die steel	Rolled bar; ½ hr. 735° C., furnace cooled.	219	102	232	406	710
10	B.S. 224 No. 1 hot die steel	Rolled bar; ½ hr. 750° C., furnace cooled.	566	88	194	406	823
10	B.S. 224 No. 1 hot die steel	½ hr. 750° C., oil quenched.	257	67	710	385	823
10	B.S. 244 No. 1 hot die steel	½ hr. 750° C., oil quenched; ½ hr. 350° C.	273	71	467	331	823
10	B.S. 224 No. 1 hot die steel	½ hr. 750° C., oil quenched; ½ hr. 500° C.	288	76	366	323	823
10	B.S. 224 No. 1 hot die steel	½ hr. 750° C., oil quenched; ½ hr. 650° C.	328	83	275	406	823
11	B.S. 224 No. 5 hot die steel	Rolled bar; ½ hr. 810° C., furnace cooled.	381	67	348	454	763
11	B.S. 224 No. 5 hot die steel	½ hr. 810° C., water quenched.	137	69	823	661	792
11	B.S. 224 No. 5 hot die steel	½ hr. 810° C., oil quenched.	174	74	823	639	792
11	B.S. 224 No. 5 hot die steel	½ hr. 810° C., oil quenched; ½ hr. 350° C.	288		527	618	
11	B.S. 224 No. 5 hot die steel	½ hr. 810° C., oil quenched; ½ hr. 500° C.	316	103	441	481	763
11	B.S. 224 No. 5 hot die steel	½ hr. 810° C., oil quenched; ½ hr. 650° C.	367	86	366	548	763
12	Non-distorting die steel	Rolled bar; ½ hr. 850° C., furnace cooled.	267	107	257	315	823
12	Non-distorting die steel	½ hr. 975° C., oil quenched.	192	99	763	366	823
13	Tungsten hot die steel	Preheated at 800° C.; 1,140° C., oil quenched; ½ hr. 535° C.	387	161	543	418	527
15	Austenitic stainless steel	Rolled bar.	387	229	223	275	165
Hardfacing Alloys							
16	Stellite 1	Sand cast.	11	—	598	606	—
17	Stellite 12	Sand cast.	69	—	511	535	—
18	Stellite 6	Sand cast.	142	100	429	496	462
19	Deloro C	Sand cast.	189	87	287	294	312
20	Deloro C.26	Sand cast.	162	43	406	385	366
Gas Turbine Alloys							
21	Stellite 7	Sand cast.	493	388	348	483	407
22	Stellite 8	Sand cast.	252	252	360	470	450
23	Stellite 422–19	Sand cast.	368	188	331	481	406
24	Stellite X.40	Sand cast.	390	251	294	429	435
25	H.R.C.M.	Investment cast.	75	27	153		227
26	G.19	Investment cast.	105	48	232		232
27	G.39 (Supplier A)	Investment cast	166	97	223	263	275
28	G.39 (Supplier B)	Investment cast.	102	48	223	263	247
29	Nimonic DS	Rolled bar; 10 hr. 1,050° C., furnace cooled.	410	142	171	202	202
30	Nimonic 75	Rolled bar; 10 hr. 1,050° C., furnace cooled.	451	172	301	247	247
31	Nimonic 80	Rolled bar; 8 hr. 1,080° C.; 16 hr. 700° C.	561	192	301	315	232
32	Nimonic 90	Rolled bar; 8 hr. 1,080° C.; 16 hr. 700° C.	536	176	357	315	223

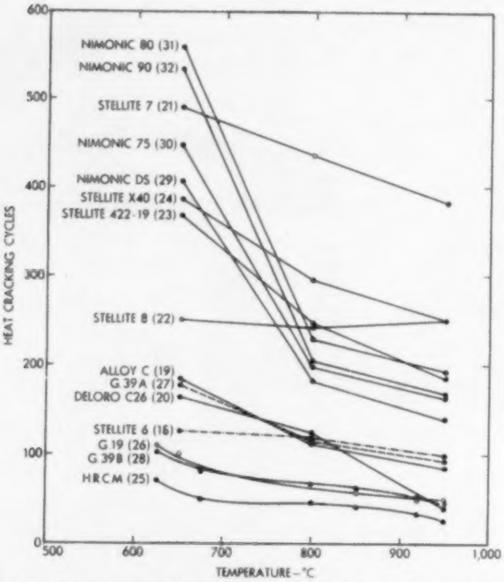


Fig. 5.—Crack resistance v. temperature of some heat resistant alloys.

harden or remain hard, depending on their treatment before testing, and show a marked drop in crack resistance at this higher temperature.

Hardfacing Alloys

The crack resistance of the three cobalt-base alloys is proportional to their hardness, as with the hot die steels. It is interesting to note that at 950° C. the crack resistance of the alloy (18) used for hardfacing forging tools is similar to B.S. 224 No. 5.

Gas Turbine Alloys

In this group of alloys, tests were also carried out at intermediate temperatures to obtain a more accurate picture of heat cracking versus temperature. The results are shown in Fig. 5, from which it is evident that the nickel-base alloys have the best resistance to thermal cracking at 650° C., and are then overtaken by the cobalt-base alloys at a temperature below 800° C. Comparing Stellite 7 and Stellite X.40 at 950° C., it appears that the addition of 10% nickel to the latter has lowered the heat cracking resistance in the same way as the addition of 15% nickel in Stellite 422–19 shows lower results than Stellite 8.

Effect of Flame Variations

To determine the effect of altering the flame conditions, samples of Nimonic 80 and Nimonic 90 were tested at 950° C. as follows :—

Flame setting	*Standard*	*Excess Acetylene*	*Oxidising*
Nimonic 80	192	191	154
Nimonic 90	176	166	143

It is evident that the standard test flame is not unduly critical, and what is usually termed a reducing flame does not affect the heat cracking results obtained with these nickel-base alloys on this test.

Examination of Test Faces

The test face of the gas turbine alloys, after failure at 950° C., was photographed at a magnification of ×5, and typical examples are shown in Figs. 6–9.

Microscopic Examination

The test face of a number of specimens was lightly ground to give a suitable metallic surface for polishing

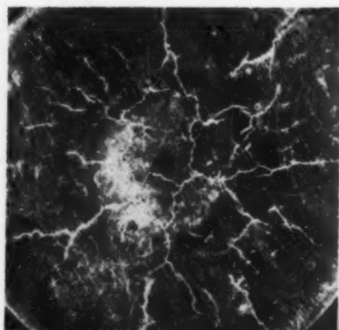


Fig. 6.—Stellite 8 (22) test face after 252 cycles at 950° C. ×5

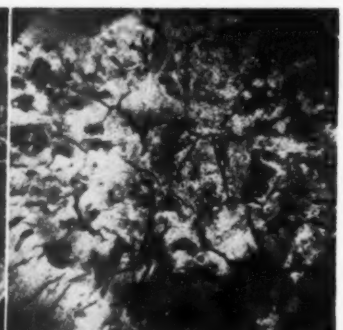


Fig. 7.—Stellite X.40 (24) test face after 251 cycles at 950° C. ×5

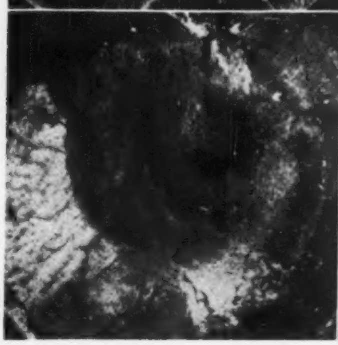


Fig. 8.—G. 39 (27) test face after 48 cycles at 950° C. ×5

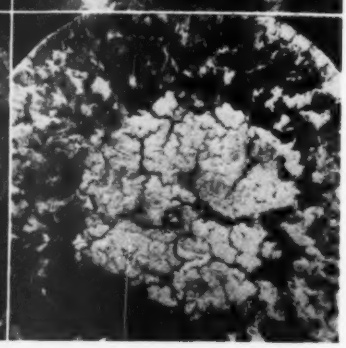


Fig. 9.—Nimonic 90 (32) test face after 176 cycles at 950° C. ×5

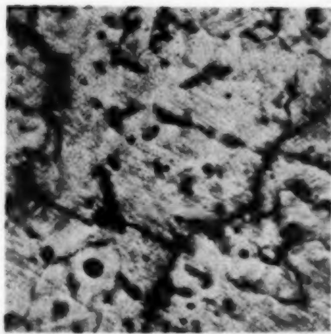


Fig. 10.—Stellite 8 (22) after 252 cycles at 950° C. Etched Murakami's reagent. ×200

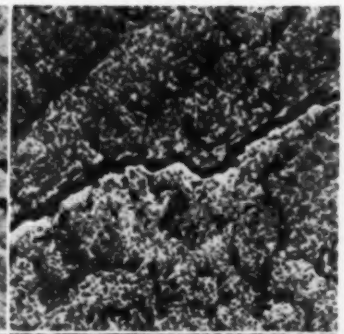


Fig. 11.—Stellite X.40 (24) after 251 cycles at 950° C. Etched Murakami's reagent. ×200

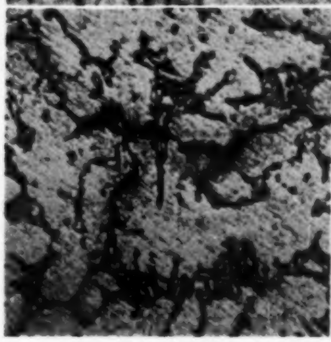


Fig. 12.—G.39 (27) after 48 cycles at 950° C. Etched Murakami's reagent. ×200

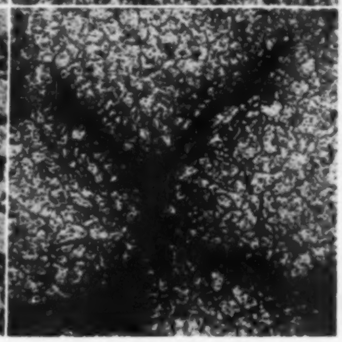


Fig. 13.—Nimonic 90 (32) after 176 cycles at 950° C. Etched Murakami's reagent. ×200

and etching. Some of the structures obtained are shown in Figs. 10–13 at a magnification of ×200. In general, the thermal cracking follows the hard carbide-rich constituent, and this is particularly evident in the cast Stellite alloys and H.R.C.M. In the Nimonic alloys, where the precipitated phase is broken up by forging or rolling, this is not so evident.

Hardness

The hardness of the test faces before and after testing at 650° C. and 950° C. is recorded on Table III. The lower test temperature lies in the tempering range for the steels, and those tested in the hardened condition have softened. Those tested in the soft condition all show a small increase in hardness, which may be attributed to the work hardening effects of the cyclic quenching. At the higher test temperature, all the steels are hardened or remain hard, the one exception being the austenitic stainless steel (15).

Conclusion

It is evident from the great reduction of cycles to failure brought about by changing from air cooling to water cooling, that in the present test it is the rate of cooling which is the critical factor. Whilst the results obtained with this test appear to give a good indication of the relative results obtained in industrial practice with different grades of cobalt-base alloys, it is evident that further work should explore the effect of varying the rate of heating. The heating rates encountered in industry are widely varied, as shown below, and are very rapid when contact with molten metal is involved.

Component	*Heating Medium*	*Cooling Medium*
Metal casting mould	Molten metal	Air
Hot forging, shearing, extrusion equipment	Hot metal	Air or water
Internal combustion engine valves	Hot gas	Cool metal
Gas turbine blades	Flame	Air

Increasing the rate of heating in the present test will give a steeper heat gradient from the test surface and increase the compression stresses and strains. For a better knowledge of the thermal cracking resistance of alloys, it will therefore be necessary to make tests at a variety of heating and cooling rates.

Acknowledgments

This work was carried out in the Research Department of Deloro Stellite, Ltd., and the author wishes to thank his colleagues Mr. J. R. Gault, B.Sc., B.Com., and Mr. S. Grainger, B.Sc., for assistance in preparing the paper. Also Mr. G. Mead for the testing and photomicrographic work, Messrs. Henry Wiggin and Co., Ltd. for the supply of Nimonic specimens, and the British Cast Iron Research Association for nodular iron specimens.

Special Furnace for India

A CONTRACT has recently been placed with Birlec-Efco (Melting), Ltd., by Electro Metallurgical Works Private, Ltd., for a special direct arc melting furnace. It is to be installed at Dandeli, which is in the state of Mysore, India. When completed, it is believed that it will be the only furnace of its kind in India. The furnace, arranged for 90° nose tilt, will be hydraulically tilted. Rated at 1,200 kVA., the plant will be used for the production of ferro-manganese. Some of this material, which is used as an alloying element for steel, will be supplied to the new Durgapur steelworks for use in the production of special steels. With a total value of about £40,000, this contract was secured by Birlec-Efco (Melting), Ltd., against severe Continental competition.

Effect of Aluminium on Density of Electrical Steels

By R. J. Bendure

Senior Chemist, Research Laboratories, Armco Steel Corporation, Middleton, Ohio, U.S.A.

An investigation into the effect of aluminium, silicon, copper and manganese on the density of electrical steels shows that manganese has no measurable effect, and that copper, in the range usually found in this type of steel would affect the density by less than 0·01. A formula is given relating density with the silicon and aluminium contents.

FOR the accurate determination of the magnetic properties and lamination factors of electrical steel sheets, the density of the steel must be known. Standard practice for many years has been to base such tests on density values specified by the American Society for Testing Materials.[1] These values have been assigned for each of four ranges of silicon content. The validity of this practice needs to be reviewed since in recent years aluminium has frequently been substituted for silicon in certain grades of electrical steel. A study was therefore made to determine the effect of aluminium, silicon, and certain other elements on the density of electrical steel.

Eleven samples of thin bar, selected from different hot-rolled silicon grades, were used for the experimental work: the analyses are set out in Table I. Blanks measuring 2 × 3½ in. were sheared from the hot-rolled bar stock for measurement of density. Surface irregularities and scale were removed by making a skin pass with a shaper, and the samples were then degreased, given a light pickle in dilute hydrochloric acid and dried in an air blast. Densities were determined by the weight-in-air/weight-in-water method. Water temperatures were measured to 0·1° C., and corrections were made for the suspension system. Using this method of measuring density, the maximum variation between duplicate determinations was found to be 0·0008 g./cc. For use in the correlation studies, the density values were rounded off to the nearest 0·001.

To determine the effect of composition on density, a graphical multiple correlation study was made. Of the constituents present in electrical steel, only silicon, aluminium, copper, and manganese are present in amounts sufficient to have any appreciable effect on density. Consequently, only these four elements were included in the study.

The graphical multiple correlation procedure is discussed at length by Ezekiel[2] and will not be described here. The final curves are shown in Figs. 1, 2, 3, and 4, but it should be pointed out that these curves cannot be used to determine density directly because the densities indicated on the ordinate have no real significance. The slopes of these curves, however, are significant and were found to be as follows:

Element	*Slope Symbol*	*Slope* (Density increase per 1%)
Silicon	b_1	−0·05905
Aluminium	b_2	−0·11333
Copper	b_3	+0·04444
Manganese	b_4	0·000

The regression equation for this correlation would be represented by

$$X = a + (b_1 \times \mathrm{Si}\,\%) + (b_2 \times \mathrm{Al}\,\%) + (b_3 \times \mathrm{Cu}\,\%) + (b_4 \times \mathrm{Mn}\,\%) \qquad (1)$$

where b_1, b_2, b_3, and b_4 are the slopes of the lines found graphically. The value for a (which in this case is the density of pure iron) can be determined by substituting the known values in equation 1 so that:

$$\Sigma\ \text{Determined density} = 11a^{*} - 0{\cdot}05905\,\Sigma\,\mathrm{Si}\,\% - 0{\cdot}1133\,\Sigma\,\mathrm{Al}\,\% + 0{\cdot}0444\,\Sigma\,\mathrm{Cu}\,\% + 0{\cdot}000\,\Sigma\,\mathrm{Mn}\,\% \qquad (2)$$

Solving the above equation for a yields a value of 7·8508.

The regression equation, therefore, becomes:

$$\text{Density} = 7{\cdot}8508 - 0{\cdot}05905\,\mathrm{Si}\,\% - 0{\cdot}1133\,\mathrm{Al}\,\% + 0{\cdot}0444\,\mathrm{Cu}\,\% \qquad (3)$$

The density of pure iron has been established to be 7·86 and the value for a should not differ much from this. The fact that the value found in this study is slightly lower could be due to the combined effect of other elements present in trace amounts, but which were not included in the correlation study.

The equation currently used by A.S.T.M. for calculation of density for scale-free electrical steels is:

$$\text{Density} = 7{\cdot}865 - 0{\cdot}065\,\mathrm{Si}\,\% \qquad (4)$$

In Table II are set out the determined densities, the calculated densities from the equation derived in the present work (equation 3), and the calculated densities from the A.S.T.M. equation (equation 4). It will be noted with the exception of sample 2, that the calculated values by equation 3 are in excellent agreement with the determined values. For sample 2, the difference amounts to 0·011. When the determined values are

TABLE I.—ANALYSIS OF THIN BAR

Sample	Si %	Al %	Cu %
1	1·38	0·005	0·18
2	1·30	0·42	0·20
3	2·15	0·030	0·19
4	2·11	0·30	0·22
5	2·79	0·005	0·082
6	2·94	0·46	0·20
7	3·24	0·004	0·21
8	3·34	0·80	0·13
9	3·42	0·005	0·12
10	3·75	0·004	0·085
11	4·79	0·005	0·069

* Each sum is the total of the values obtained in the 11 samples: therefore 11a is used in the equation.

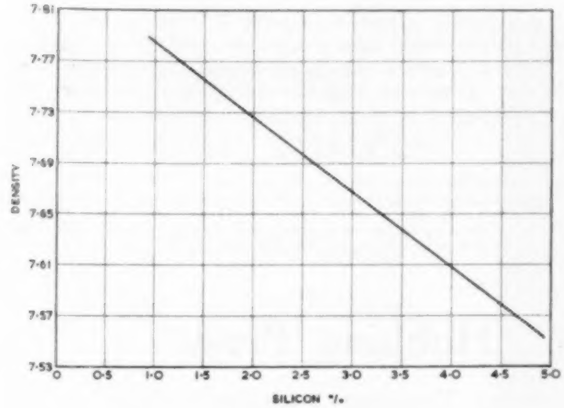


Fig. 1—Final approximation of silicon.

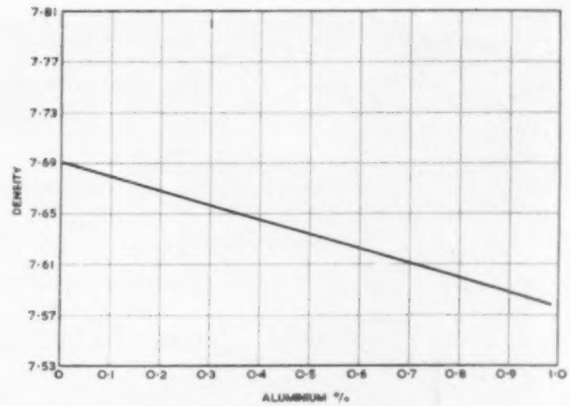


Fig. 2—Final approximation of aluminium.

TABLE II.—CALCULATED VS. DETERMINED DENSITY

Sample	Determined	Calculated*	Difference	Calculated†	Difference
1	7·776	7·777	−0·001	7·775	+0·001
2‡	7·746	7·735	+0·011	7·780	−0·034
3‡	7·725	7·729	−0·004	7·725	0·000
4‡	7·702	7·702	0·000	7·728	−0·026
5	7·687	7·689	−0·002	7·684	+0·003
6‡	7·636	7·634	+0·002	7·674	−0·038
7	7·663	7·668	−0·005	7·654	+0·009
8‡	7·573	7·569	+0·004	7·648	−0·075
9	7·648	7·654	−0·006	7·643	+0·005
10	7·631	7·633	−0·002	7·621	+0·010
11	7·576	7·571	+0·005	7·554	+0·022

* Using Equation 3 (Armco)
† Using Equation 4 (A.S.T.M.)
‡ Aluminium present in added amounts

compared with the values by the A.S.T.M. equation, reasonably good agreement is obtained only for those samples in which the aluminium content is residual (except for Sample No. 11 which differed by 0·022). When aluminium is present in added amounts the agreement is poor.

To determine the range of aluminium to which the equation might be applied, density determinations were made on two samples containing aluminium in excess of 2·5%. Chemical analyses and the density values are shown in Table III. Differences between determined and calculated values (0·02 in one case and 0·03 in the other) are somewhat greater than with the previous

TABLE III.—CALCULATED VS. DETERMINED DENSITY—HIGH ALUMINIUM CONTENTS

Sample	Si %	Al %	Cu %	Determined Density	Calculated* Density	Difference
21	0·027	2·74	0·037	7·57	7·55	+·02
22	0·15	3·46	0·020	7·50	7·47	+·03

* Using Equation 3 (Armco)

samples. It is believed that this might indicate that the slope of the aluminium line is not constant; i.e., when it is extrapolated so far beyond the limits of the original study a slight error is introduced. This is confirmed by the work reported by Sykes and Bampfylde[3] on iron-aluminium alloys. Their plot of density *vs.* aluminium (up to 16%) results in a curve rather than a straight line.

In order to obtain more accurate calculations of density when the aluminium content exceeds 1%, it would be necessary to make a new study of a series of samples with higher aluminium contents. However, equation 3 appears to be satisfactory for the electrical steels now in use.

In view of the marked effect of aluminium on density indicated by the present study, it would seem that aluminium, when present in added amounts, should be taken into account in density calculations. Copper in the range usually found in electrical steel would affect

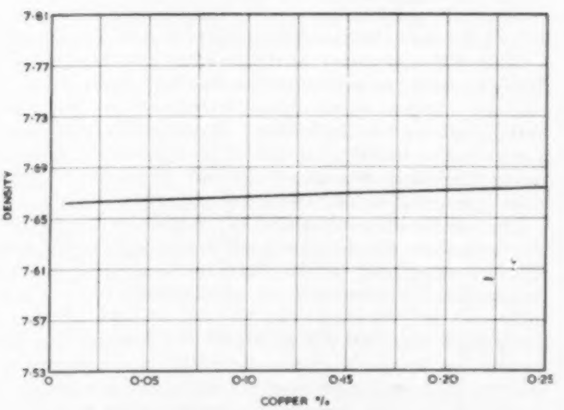


Fig. 3—Final approximation of copper.

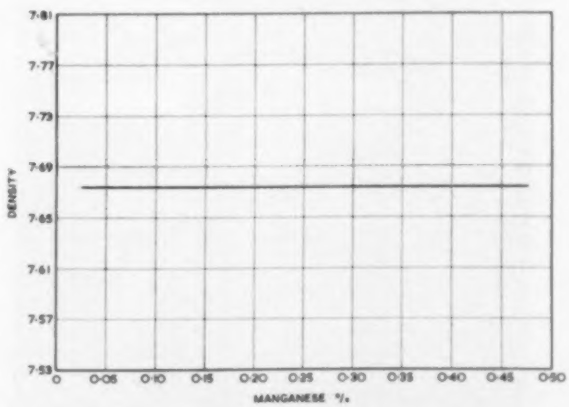


Fig. 4—Final approximation of manganese.

the density by less than 0·01. Manganese has no measurable effect. For practical purposes, therefore, it appears that the following simplified formula will give satisfactory accuracy for density calculations for electrical steels, in the ranges of silicon 1–5% and aluminium 0–1%:

$$\text{Density (g./cc.)} = 7 \cdot 85 - 0 \cdot 059 \text{ Si\%} - 0 \cdot 113 \text{ Al\%} \qquad (5)$$

If desired, equation 5 could be further simplified without introducing an appreciable error by the following:

$$\text{Density} = 7 \cdot 85 - 0 \cdot 059 (\text{Si\%} + 2 \text{ Al\%}) \qquad (6)$$

For example, a steel containing 3% silicon and 0·5% aluminium would have a calculated density by equation 5 of 7·617 and a calculated density by equation 6 of 7·614. As may be seen, the error introduced by the use of equation 6 is of no practical significance.

REFERENCES

1 A.S.T.M. Standard No. A34-55; Section 8.

2 "Methods of Correlation Analysis," Mordicai Ezekiel, New York, 1930, John Wiley & Sons, Inc.

3 "The Physical Properties of Iron-Aluminium Alloys," C. Sykes and J. W. Bampfylde, *Jour. Iron & Steel Inst.*, 1934, **130**, 389.

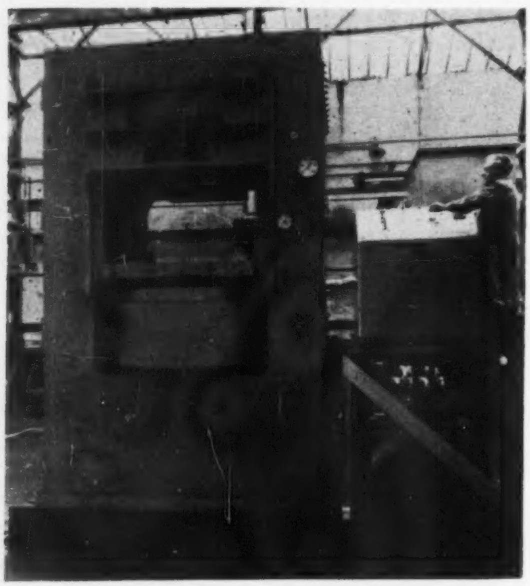
5,000 Ton Hydraulic Hobbing Press

Forming Moulds for the Drop Forging Industry

The Hydraulic Engineering Co., Ltd., Chester, have recently completed a 5,000 ton hobbing press for the largest drop forging organisation in the U.K. The latter organisation has been operating a 2,000 ton hydraulic hobbing press for the past three years, and is now extending its range of operations.

The hobbing process, which has long been in use in the plastics industry has only comparatively recently been adopted by the drop forging industry, but is now arousing increasing interest as a means of forming relatively simple moulds much more quickly and cheaply than the normal die sinking process. Dies for producing such things as spanners, small hand tools, rocking levers and small crankshafts are being made by hobbing.

In the hobbing process, a female die, or mould, is formed from a master male die of special heat treated steel. The male die is forced very slowly into a blank of normalised steel until the required depth is reached. The mould is then finished by machining, heat treatment and a final grinding or polishing operation. The speed of penetration must be as slow as possible to avoid splitting the blank. Speeds as low as 0·01 in./min. can be obtained by pump selection and a flow control valve.



To increase its versatility and utilisation, the press is so designed that it can also be used for hot forging, or cold flow forging, at a reduced tonnage and a higher ram speed. The 5,000 ton press illustrated is capable of the following speeds:

Load (tons)	Speed (in./min.)
Up to 1,500	14
Up to 5,000	0·4 with 4 h.p. pump
	0·3 with 3 h.p. pump
	0·2 with 2 h.p. pump
	0·1 with 1 h.p. pump

and by means of the flow control valve the last figure can be reduced to 0·01 in./min.

The press weighs 73 tons. The frame is made up of eight 3½ in. thick steel plates securely keyed together, and provides for a work table 40 in. square, and 32 in. daylight. The single upstroking ram has a diameter of 48 in. and a stroke of 8 in., and two 60 h.p. 1,440 r.p.m. motors drive the pumps. A sliding guard is fitted at the front of the press, with a Perspex window, and a fixed steel plate guard at the rear.

Dorman Long Development Plans

Dorman Long (Steel), Ltd., who last year completed their £60 million post-war development programme, recently announced plans for further improving efficiency and increasing iron and steelmaking capacity. The Iron and Steel Board has approved proposals by the company to install a sixth 360 ton tilting open hearth furnace and a third 600 ton mixer at their Lackenby steel plant. Facilities will be provided for the full application of tonnage oxygen steelmaking techniques to all open hearth furnaces at Lackenby. Approval has also been given to the building at the Clay Lane blast furnace plant, Cleveland Works, of a third 27 ft. 6 in. hearth blast furnace of 1,500 tons a day capacity.

The total estimated capital expenditure is £6,819,000. Work on these developments will begin immediately and member companies of the Dorman Long group will be responsible for construction. It is anticipated the new units will be in operation by the end of 1961. Dorman Long ingot capacity will be raised to 2,600,000 tons per annum by these developments which are designed to provide sufficient ingot steel to allow full advantage to be gained from the increasing potential of the company's existing rolling mills.

Preheating Titanium Billets

Walking Beam Electric Furnace Installation

By P. Bates, C. Westwood and B. E. Jarvis

(*AEI-Birlec, Ltd.*)

General view of one of the furnaces showing the charge end and the control panel

The purpose of this article is to describe in some detail two furnaces constructed by AEI-Birlec, Ltd., at the Waunarlwydd Works of I.C.I. Metals Division, for the preheating of forged billets prior to the rolling operations.

THE hot manipulation of titanium presents difficulties, in that the material has a low density and therefore a heat content value approximately half that of steel. As the heat radiation rate is of the same value as that for steel, for successful hot working the handling time of the hot billet must be reduced to an absolute minimum. Titanium is susceptible to gaseous contamination, particularly by hydrogen and oxygen, so that direct firing by gas or oil fuel was not considered for the preheating of forged titanium billets prior to rolling at the Waunarlwydd Works of I.C.I. Metals Division, and the equipment was designed to be heated by electric power.

The maximum output required from the plant was 2,600 lb./hr., and to ensure flexibility in operation and to facilitate maintenance, it was decided to install two independent furnaces, each capable of heating half the required output. The furnaces were designed for continuous operation and to handle billets in round and square cross sections ranging in size from 5 in. diameter by 36 in. long, to 2½ in. square by 72 in. long. The metal was to be heated to 1,100° C., with a uniformity of ± 10° C.

The furnace equipment supplied had to satisfy the requirements of high operating temperature, a heavy charge weight to be handled continuously, and a fast speed of discharge of the heated billet. Consideration of these factors resulted in the adoption of a three-track walking beam furnace, incorporating a lift-off roof and heated hearth, and sealed to permit the future use of protective gas atmospheres in the furnace chamber.

General Description of Furnace and Auxiliaries

Hearth

The hearth is arranged with four fixed and three moving beams. The three moving beams are secured to a common base, sealed from the outside atmosphere by means of blades engaging liquid-filled troughs. The liquid is circulated at low temperature by a conventional pumping and cooling system, the hot liquid being drawn from the seal over weirs, which also discharge the seal liquid displaced during the beam traverse movements. The hearth movement is achieved by two hydraulically operated cylinders, one for the traverse and one for lifting and lowering. The total movement for each " walk " is 7 in. in the vertical direction and 4½ in. in the longitudinal direction.

The hearth beams are faced with pre-formed refractory bricks, providing a series of " V " notches to locate the billets. Expansion slots are incorporated and are designed to preserve a fixed pitch along the whole length of the beam. A feature of the beam construction is the overlapping on the joint face of the fixed and moving beams, preventing direct radiation from the furnace on to the operating mechanism below. The design, however, allows for the removal of the beams for maintenance purposes by lifting vertically upwards.

Heating elements are included in both fixed and moving beams, to ensure uniformity of billet temperature. These elements are protected by a system of cover tiles located in grooves in the beam bricks. The elements are designed to run at a low power density to ensure long life. All the hearth heating elements are terminated at the charge end of the furnace, those of the fixed beams in conventional lead-outs and those of the moving beams in flexible aluminium braid to permit the necessary movement.

Removable Roof

The furnace roof is built as a unit which can be lifted bodily for access to the chamber. The roof brickwork consists of semi-refractory and insulating bricks in a sprung arch construction. Heating elements are arranged in the roof in two zones, which, when working in conjunction with the hearth zone, combine to give excellent

temperature uniformity without the use of fan circulation.

The main weight of the roof is supported at four points by a pin and socket arrangement, thus ensuring accurate location after lifting and replacing. The lead-outs from the furnace element and compensating cables from the thermocouples are all brought out to easily disconnected junction boxes.

Charging

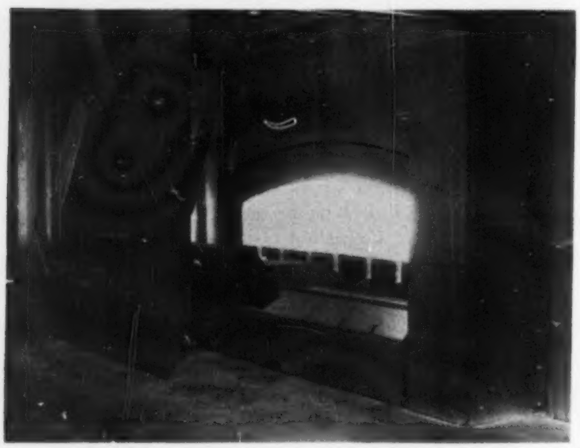
There is an electrically and pneumatically operated billet charging machine consisting of three sets of notched arms, raised and lowered by twin pneumatic cylinders. The arms are propelled into the furnace by a geared chain drive coupled to an electric motor. At the commencement of a charging cycle the operator places billets on to the charging arms and makes an electrical contact by push-button to initiate the sequence. The arms rise, the door opens, the machine runs into the furnace, deposits the charge on the track, withdraws, and the charge door closes. This door is of the sloping type and is pneumatically operated.

Beam Movements

Three moving beams are mounted in the furnace hearth and may be used as three separate tracks for short billets or in combination for longer pieces. The walking movement of the beams is of the conventional rectangular pattern, the rest position being in the forward lowered position. On initiation by the sequence switch (described in more detail later) the beam moves backward in the down position to a position one pitch behind the billets supported on the fixed hearth. The beam then lifts all billets and travels forward one pitch, finally lowering the billets on to the hearth one notch further forward. The beam remains in the lowered forward position until the next impulse from the sequence switch.

Discharge Door

This is of the vertically operated type, lowering to open. This method of operation enables the door supporting structure to be built into the fixed base of the furnace so that the roof structure is independent and may be lifted without reference to the door gear. The door is hydraulically operated by a single long-stroke hydraulic cylinder. Automatic clamping of the door to the furnace face is also provided by means of two further hydraulic cylinders mounted on either side of the door, thus ensuring a good heat and atmosphere seal.



View showing the discharge end of one of the furnaces with the overhead discharger opposite the door.

Discharge Gear

The discharger runs on an overhead rail track mounted on a steel frame separated from the furnace structure to avoid interference with the removal of the roof. It comprises a carriage fitted with projecting arms and moved to or from the furnace opening by a chain drive. The drive is arranged so that the carriage is accelerated and de-accelerated slowly to ensure smooth operation. The main chain drive is actuated by means of a gearbox and motor coupled with an electro-magnetic brake to ensure stopping immediately the drive is switched off, as the position of the discharge arms for lifting and lowering in the furnace is critical.

The discharge arms are arranged in three pairs to facilitate the discharge of any combination of heated billets (one, two or three). These arms comprise a double link, providing two movements. The lifting of the billet from the beam in the furnace prior to the operation of the discharge carriage is effected by three short-stroke pneumatic cylinders, giving individual operation to whichever pair of discharge arms is to be operated. When the required billets have been lifted from the beam brickwork, the discharge carriage is driven away from the furnace towards a roller conveyor track leading to the mill.

When the arms are clear of the door structure, the door commences to close to ensure minimum heat loss from the furnace, and at the same time a long-stroke pneumatic cylinder attached to all three pairs of arms operates. This means that the discharge arms supporting the heated billets are lowering in the direction of the roller conveyor at the same time as the carriage is moving out. This combined movement cuts the discharge time to a minimum of about ten seconds.

When the long-stroke cylinder has completed its movement, the appropriate short-stroke cylinder operates and the discharge arms depress still further, passing between the rollers on the constantly driven roller track. As the billet is deposited on this track it immediately moves away to the rolling mill. The long-stroke cylinder then retracts and returns all three pairs of discharge arms to the rest position at beam level, ready for the next billet discharge.

The long-stroke cylinder is mounted high in the discharge carriage structure, away from the radiated heat of the furnace. The short stroke cylinders which, by necessity, are mounted lower down attached directly to the discharge arms, are protected from the heat by radiation baffles.

Electrical Equipment

The electrical equipment used on this installation has separate sections for the heating circuits and the sequence circuits. The heating circuits are those directly concerned with the heating elements in the furnace: the sequence circuits are those used to control the movements of the billets through the furnace, and on to the roller conveyor, which conveys the billets to the mill. The main power supply at 520 volts, 3 phase, 50 cycles is brought into the main contactor panel through a main isolator which is interlocked with both the door of the

(1) B only. (3) A, then B, then C

(2) A, then C (4) A, B and C together

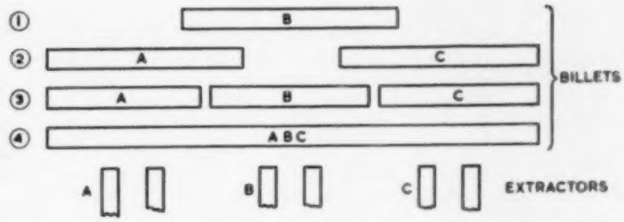


Diagram showing the possible settings for the sequence control of the discharging operation according to the number and size of billets required for the rolling programme.

heating circuit section and the sequence circuit section.

Heating Circuits

The heating circuits are directly fed from the main isolator via a safety contactor; this contactor switches off the heating elements, to prevent overheating under fault conditions in conjunction with the safety instruments fitted in each heating zone of the furnace. Once tripped, the furnace cannot reset itself without the operator becoming aware of a fault having occurred and investigating the cause.

In this installation the safety contactor includes in its functions protection on the following points: earth leakage; zone contactor overload; and cooling water flow failure. Each zone is fitted with individual instantaneous earth leakage and overload relays and indicators ensuring that any failure will be immediately located and action taken to shut down the furnace. Flow failure warning equipment is fitted in the beam seal cooling system, and operates both the safety contactor and alarm in the event of failure.

The temperature of each zone is controlled by Honeywell circular scale indicating on/off controllers, via zone control contactors of Contactor Switchgear manufacture. From the zone control contactors the 520 volt supply is fed to air-cooled step-down transformers which provide the necessary low voltage for the furnace elements. The transformers are fitted with tappings in order that the rating of each zone can be adjusted.

The control instrument cubicles were supplied by I.C.I., Ltd. Upon these are mounted the temperature control and safety instruments for each zone, together with the zone hand control switches and indicator lamps. Thermocouples used with the instruments are duplicated in each sheath, one being connected to the control instrument and the other to the zone safety instrument. This gives a positive check against each thermocouple without removing it from the furnace.

Sequence Circuits

The sequence circuits for this installation required special consideration due to the range of billets to be heated and the short time allowed for removing a billet from the furnace and depositing it on the conveyor to the mill stand. It was also essential that no unnecessary labour be required; indeed, it was understood that only one operator would be available at the discharge end of the installation with a further operator loading the charge end. It was therefore necessary that the furnace should operate automatically once a given type of billet or billet arrangement was selected from the pattern of billets shown in the diagram.

Movements to be controlled by the sequence circuit are of three main types, hydraulic, pneumatic and motorised. The hydraulic system is divided into two circuits, one high pressure and one low pressure, the high being used for beam movements and the low for doors, etc. The pneumatically operated movements are those on the extractor carriage and are all controlled by solenoid valves. The in and out movement of the carriage is the only motorised movement.

The sequence is initiated by the discharge operator pressing a start button, having first set the discharge arrangement according to the pattern of billets to be discharged. The operator normally initiates discharges when required by the mill operator, but when on long runs of one billet arrangement, a process timer is included to prevent the operator discharging the furnace too frequently; it also gives a visual warning that billets are ready for discharge, this indication being held until two or three billets of a pattern are discharged.

When the sequence starts, the discharge door is first unclamped and lowered. As the door opens, the extractor carriage begins to move into position. As the carriage is run up to the furnace the extractor arms enter slots underneath the billet or billets to be discharged. The discharge selector then takes effect and lifts only the appropriate arms. It is from this point that the hot billet must be moved and deposited without delay on the discharge conveyor.

The carriage moves away from the furnace and as soon as it is clear of the furnace hearth the sequence switch causes the carriage to lower whilst continuing to reverse. As the carriage reaches the fully reversed condition the extractor arms drop between the conveyor rollers, allowing the billet to be carried away. The discharge door is closed and clamped as soon as the extractor carriage and billets are clear of the furnace.

The first portion of the sequence has now been completed and the next step depends on the billet discharge pattern. If a single large billet has been discharged the next billet will be brought into position. If, however, more than one billet is to be discharged, the sequence will wait in a rest condition until the start button is again depressed, the sequence will then be repeated for a second billet and, if required, wait again to discharge a third. Once the final billet of a given row of billets has been discharged the furnace beams will carry out either one or two movements according to the size of billets being handled.

It can be seen from the preceding description that five actions are used to make a complete operational sequence. The five sections are all built on to one sequence switch, which is probably most easily described as a motorised drum controller which controls both the furnace movements and, with the help of limit switches, indexes itself to the next operation. The sequence switch controls the motions entirely automatically once the operator has pressed the start button.

Variations in the sequence are covered by the setting of various rotary switches in the control circuit. Thus the furnace can be operated without discharging, either for maintenance checks on the beam operations or for

rapidly charging the furnace at the commencement of a shift. In a similar manner the charging operation can be switched off completely and only operate the discharge equipment. Another selector can be used to increase the pitch of billets.

Results

By the installation of this plant it is now possible to produce large quantities of titanium billets for the rolling mill, heated to the high rolling temperature required with a temperature uniformity better than $\pm 10°$ C. up to a maximum output of 2,600 lb./hr.

All charging, walking and discharge movements are fully automatic, depending on the pressing of a push-button to initiate the sequence.

The billets are delivered to the rolls with the very minimum of delay, and both furnaces can be continuously operated by no more than two unskilled men.

Wire Temperature Meter

EFFICIENT operational control in wire mills is at present limited by the lack of an accurate device for measuring wire temperature. If full advantage is to be taken of the higher drawing speeds that engineering and electrical machine design now make possible, it is necessary to ensure that the temperature of the wire, as it is drawn through the dies, does not rise so high that the properties of the wire or of the lubricant are impaired. With a suitable temperature-measuring instrument the maximum drawing speeds could be quickly established for various steel qualities and for different drafting schedules. The instrument could be the basis of future systems of automation and process control in wire-drawing mills, and could also be used for measuring the temperature of wire during heat treatment and in " in-line " cleaning and coating.

A reliable instrument has recently been developed for this purpose by the Addison Electric Co., Ltd.,* in collaboration with The British Iron and Steel Research Association. In the Addison meter a reading is obtained by pressing two pulleys, made of different metals forming a thermocouple, against the moving wire. The signal generated is passed through contacting brushes on the pulleys, and a connecting lead, to the measuring unit. The meter has been specifically designed for the rapid temperature measurement of moving wire, and the response time is normally only 5-10 seconds. The temperature is indicated directly on a calibrated scale in the measuring unit.

The Addison wire temperature meter removed from its special leather carrying-case.

The instrument has been calibrated, on a special rig developed by BISRA, over a speed range of 50-3,000 ft./min., a temperature range of 50-300° C.; and wire sizes from 9-16 s.w.g. The meter reading is independent of wire size and speed over the ranges tested. Accuracy is $\pm$ 5° C., which is considered to be adequate for industrial needs.

The calibration is not affected by the type of phosphate coating normally used for the drawing of high-carbon steel wire, and theoretically there are no reasons why it should be affected by tin or zinc coatings provided there is no temperature difference in the wire between the contact points on the pulleys. The problem of temperature measurement on heavily soaped wire, where it has been found that the soap transferred to the pulleys may act as an insulator, thus preventing more than one reading without cleaning, has been overcome by fitting paraffin impregnated pads that are spring loaded on to the pulleys: in this way a clean surface is always presented to the pulleys.

The Addison contact meter has proved itself in the laboratory and in industrial wire mills during extensive experimental studies. Preparation for use, by zero setting and adjustment for ambient temperature, is easy and takes less than half a minute, and the only other precaution needed is to ensure that the pulleys are clean and that the pads are impregnated with paraffin.

The instrument is of robust construction, and the measuring unit, containing the meter, is self-contained in a case approximately $10\frac{1}{2} \times 10\frac{1}{2} \times 4\frac{1}{2}$ in. and weighs just over 5 lb. An optional extra is an ever-ready leather case with a strap so that the instrument can be slung from the neck during use.

* 10/12 Bosworth Road, London W.10.

Contract Award

A £500,000 contract has been awarded by James Booth Aluminium, Ltd., Birmingham, to The English Electric Co., Ltd., for the electrical equipment for a new 148 in. four-high hot aluminium rolling mill—the largest of its kind in Western Europe—and a new 72 in. four-high cold mill. The new mills, designed and supplied by The Loewy Engineering Co., Ltd., are part of James Booth's £5 million expansion scheme, and are to be installed in the company's Kitts Green Works, Birmingham during 1961.

Stress Relieving by Flexible Furnace

Treatment of 80 ft. Fabricated Bridge Girders

THE stress relieving of very large or long welded fabrications can present quite a problem if suitable furnace accommodation is not available. This difficulty arose recently after the fabrication of four huge steel girders at the Chepstow works of the Fairfield Shipbuilding and Engineering Co., Ltd., for the new Runcorn-Widnes road bridge, which will ultimately replace the existing transporter bridge.

Some idea of the size and design of these girders may be gathered from the accompanying illustrations. Each completed girder is approximately 80 ft. long by 6 ft. high and weighs in the region of 14 tons: they are welded fabrications constructed with $\frac{3}{4}$ in. thick webs and $1\frac{1}{2}$ in. thick flanges, and stiffened at regular intervals with 8 by $3\frac{1}{2}$ by $\frac{3}{8}$ in. angles. For convenience of manufacture each girder was fabricated in two separate 40 ft. lengths which were then joined by welding to produce the complete 80 ft. girder.

Because of the importance of these girders—they will carry most of the load—very strict specifications were laid down regarding the stress relief procedure for the weld joining the halves of the girders. These were as follows: (1) heat to 650° C. at a rate not exceeding 150° C. per hour; (2) soak for a period equal to one hour per inch of the thickest part of the heated area; (3) cool to 350° C. at a rate not exceeding 100° C. per hour; and, finally, (4) allow to cool naturally to room temperature.

Flexible Furnaces

No conventional furnaces capable of accommodating such large girders were available at the Chepstow works and Electrothermal Engineering, Ltd., were invited to undertake the stress relieving operation, using their "Flexible Furnaces." These are, in effect, mats composed of ceramic beads threaded on "hairpins" of nickel alloy resistance wire: the latter are linked together to provide a series of electrical circuits capable of giving a maximum mat surface temperature of 1,000° C. Each circuit is provided with flexible leads, and by bringing in or cutting out circuits it is possible to control the mat temperature to close limits. The mats are very flexible, and in one direction can be bent to a minimum radius of 1 in.: thus they may be wrapped around the edges of plate, etc., without difficulty.

Problems Involved

Before commencing the treatment it was necessary to give careful consideration to certain problems arising from the close temperature cycle specifications, the considerable mass of metal involved and, in particular, the large surface area from which heat could be readily dissipated. In particular, the Electrothermal engineers had to determine: (1) the amount of heat input required; (2) the power necessary to provide this heat; and (3) the amount of lagging necessary to conserve the heat input. Also, because of the weight and size of the girders, the services of two cranes were required each time they were moved: consequently, forward planning of the movement of girders was essential, because the cranes were also employed on normal shop work and were not always readily available.

Fig. 1.—The first stage: marking-out the position of the lagging, mats and thermocouples.

Heat Input

With regard to the question of heat input, while it was known that the flexible furnaces were capable of producing a maximum temperature of 1,000° C. and could dissipate 50 W./sq. in., it was appreciated that they would have to be considerably underrun in order to keep to the specifications. In fact, the density actually employed was well under 25 W./sq. in.

Power Supply

The power for heating purposes was supplied by two standard 300-A. Quasi-Arc, and two 350-A. English Electric welding transformers: these are continuous rating current figures. By means of a standard earth clamp the end of each transformer lead was connected to a copper busbar, to which were attached leads from several mats. As the attachment was made by means of nuts and bolts it was an easy matter to disconnect or connect leads in order to lower or increase the temperature in any particular area as the need arose.

Thermal Insulation

Four-inch thick slab-type thermal insulation material was employed for lagging purposes. Two types were used, the prime lagging (adjacent to the metal surface) being capable of efficient results at temperatures up to approximately 800° C.: the outer or secondary lagging was also extremely efficient, but had an upper limiting temperature of about 500°–600° C. Before commencing the lagging operation it was necessary to decide the size of the area to be lagged, the number and position of the heating mats, and the number and position of the thermocouples to be used for temperature control

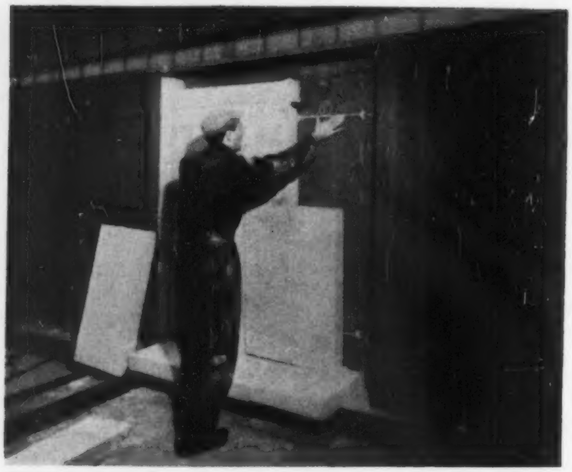


Fig. 2.—Building-up the lagging on the underside of the girder prior to laying it on the ground. This was necessary for the first two girders only.

purposes. These details were then marked on the girder (Fig. 1).

After careful consideration, it was decided that a minimum distance of 3 ft. on each side of the weld should be lagged. Prime lagging was applied to the underside of the girder and to the inside of the flanges and secondary lagging was then added in the manner shown in Fig. 2: this was done with the girder in the vertical position, the lagging being held in position by means of boards and wire rope. The girder was then turned through 90°, i.e. to the position seen in Figs. 3 and 4, the mats placed in position and the upper surface and outside of the flanges lagged in a similar manner, the total thickness of lagging being in the region of 16 in. Thermocouples were placed in position at the appropriate stages. Because of the efficiency of the crane drivers, it was possible to modify this procedure slightly for the third and fourth girders by lowering them directly on to the base lagging which remained on the shop floor when the first two girders were lifted after completion of stress relieving.

It may be mentioned that the sequence of girder treatment adopted was as follows: (*a*) prepare No. 1 girder, and while heating is in progress, prepare No. 2 girder; (*b*) while No. 1 girder cools, heat No. 2 girder; (*c*) while No. 2 cools, strip No. 1 and replace by No. 3; (*d*) heat No. 3 while No. 2 cools; (*e*) while No. 3 cools, strip No. 2 and replace by No. 4; (*f*) heat No. 4 and strip No. 3; and (*g*) allow No. 4 to cool. It was found that this sequence caused minimum delay.

Control of Heating

Temperature Recording

The flexible furnaces were positioned, under the prime lagging, in the manner shown in Fig. 6, and at strategic positions under the mats were thermocouples connected to Ether Type 800 temperature recorders. Special precautions were taken to ensure the uniformity of all the thermocouples, and to ensure that all the leads were exactly the same length, in this case 15 ft.

It should be noted that the thermocouples not only provided a means of recording the temperature in the areas concerned, but were also used to monitor the mats, or sections of mats. In other words, the operator watching the recorders could predetermine whether the temperature in any particular area under treatment should be increased or decreased (i.e., the voltage or current adjusted to cause this to happen later). This was achieved by carefully studying the general trend of the curves, and from this information determining what would happen in the near future.

In all, seventeen thermocouples were positioned at various points around each girder, some in contact with the metal surface and others buried in the lagging. By this means useful information was obtained on the temperature gradients along the girder and, also, through the lagging.

Temperature Control

Control of the heat input in order to comply with the specification cycle was achieved by varying the current output of each transformer, and at the switch-on stage the tappings were the lowest possible obtainable. The voltage and current readings were made in the conventional manner, using voltmeters and tong testers: bearing in mind that welding sets by different manufacturers and of varying age have different drooping characteristics, all measurements were taken at the terminals of the flexible furnaces. Any tendency for one area to heat more rapidly than another was corrected without difficulty, merely by cutting out of circuit the appropriate mats or sections of mats, and it was thus comparatively easy to ensure uniform heating over the entire weld area.

The general rise in temperature during heating was maintained close to specification requirements by stepping-up the output of the power sources to suit the readings shown on the recorders, at the same time adjusting

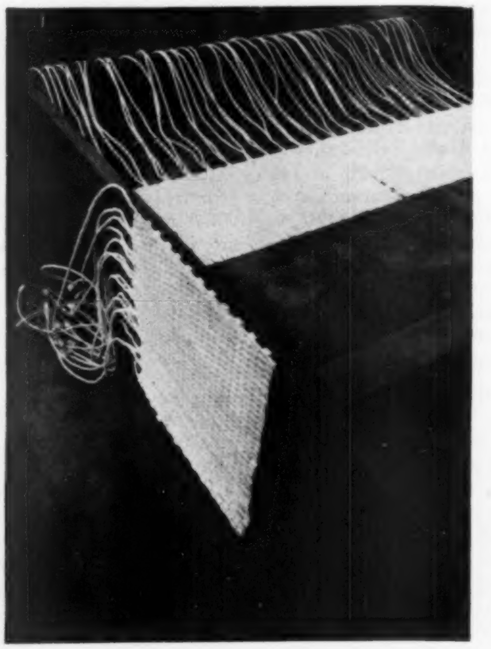


Fig. 3.—The flexible furnace in position on the girder.

any local difference in the manner just described. When the temperature in all areas reached approximately 575° C., i.e. about 75° C. below soaking temperature, the voltage and current outputs of the sets were reduced in order to avoid any chance of over-shooting the maximum temperature. It was found that interpretation of the curves shown on the recorders enabled the operators to predetermine very accurately the change of settings required.

Soaking was achieved comparatively easily, and the subsequent cooling-down stage amounted to little more than intelligent interpretation of the recordings. During the stage of cooling from 650°–350° C., the furnaces were switched on and off as necessary to maintain a steady rate of cooling in each area : this uniformity of cooling was made possible by the fact that each heater could be independently controlled. When the temperature had fallen to 350° C., all heaters were switched off

Fig. 4.—This view shows the application of the prime lagging to the upper face of the girder.

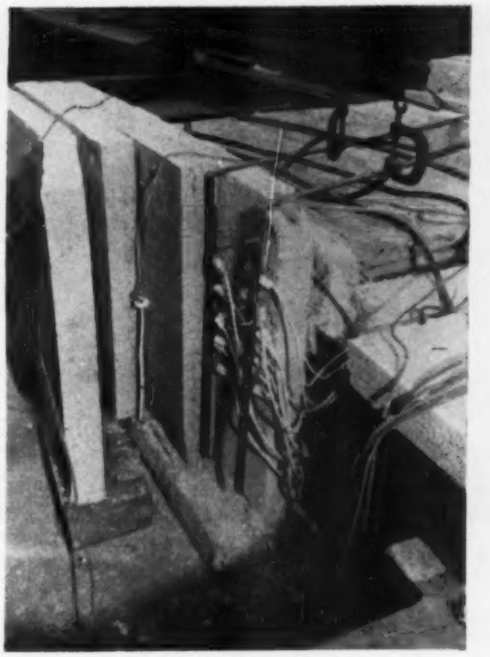


Fig. 5.—A stage in the lagging of one of the webs. Note the busbars to which the leads from the mats are attached and, at the rear, a thermocouple provided to check the temperature inside the lagging.

and the entire assembly allowed to cool naturally, without disturbing the lagging.

After the cycle had been in operation for some time, heat rising from the lower portion of the vertical flanges increased the rate of heating of the upper portion. For this reason it was essential to be able to control the heating of these upper surfaces by putting the appropriate mats out of circuit until the temperature was uniform throughout the entire flange, as shown by the thermo-

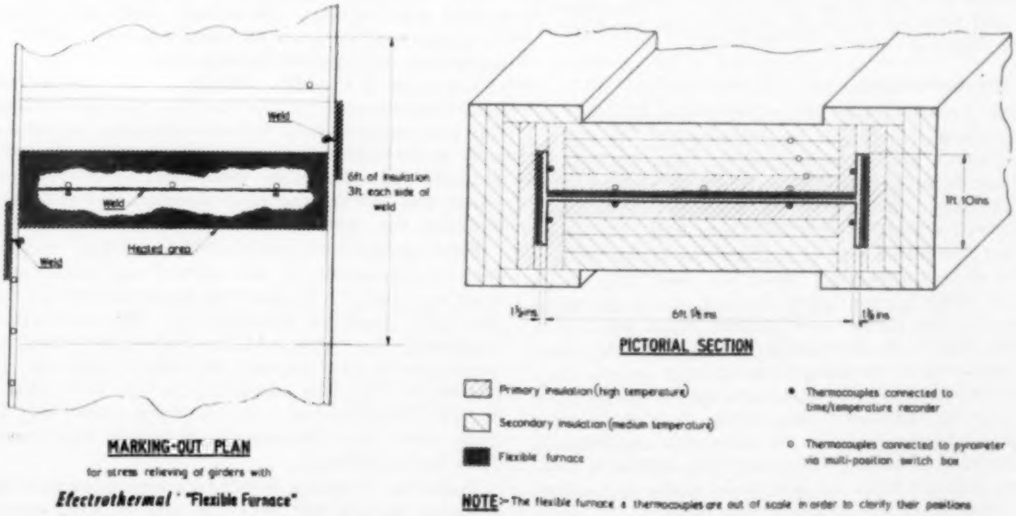


Fig. 6.—A diagram such as this was carefully prepared prior to commencing the operation.

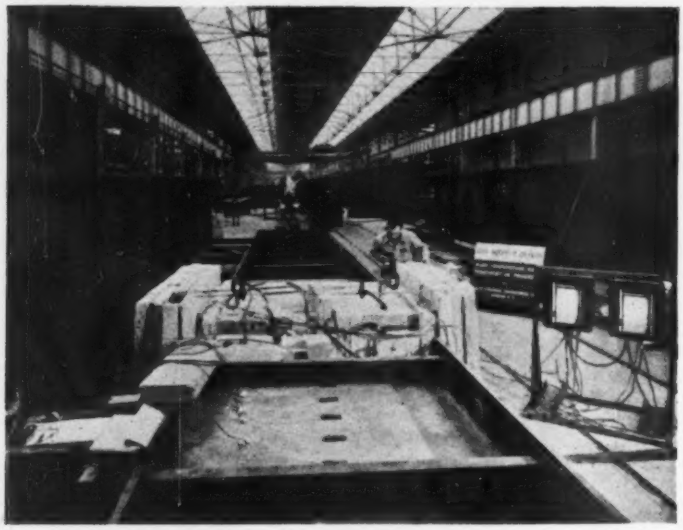


Fig. 7.—Stress relieving in operation: on the right are the two recorders to which were attached a total of twelve thermocouples.

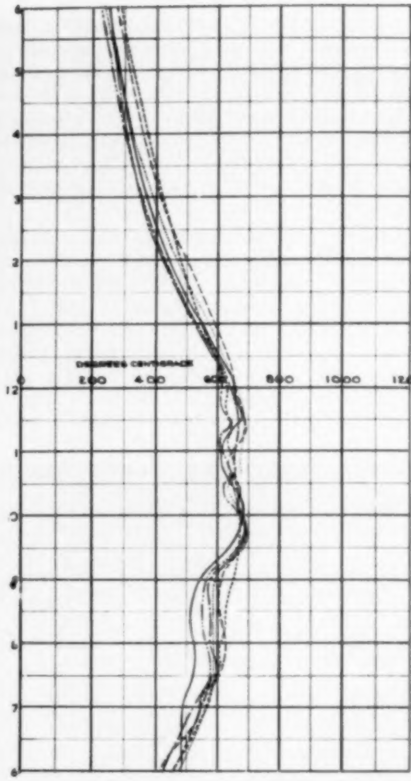


Fig. 8.—Typical temperature recordings during one of the heat treatment cycles. Note how it was possible, by controlling individual mats, to keep all six readings uniform.

couple readings. This was done simply by splitting the busbars for the flange heaters into halves connected by an earth clamp, as mentioned earlier. Thus, when it was required to slow down heating of the upper portion it was only necessary to loosen the earth clamp, remove the upper half of the busbar, and then re-fasten the clamp to the remaining half.

The very accurate control of temperature achieved at all stages was undoubtedly influenced considerably by the careful attention paid to the lagging operations. Heat losses were minimised, thereby conserving energy input and, more important, temperature gradients through the girders were comparatively small. In view of the size of the girders, the mass involved and the considerable surface area, problems could readily have arisen if the lagging had been skimped or done carelessly, and a good deal of the success of the heat treatment of these girders was definitely attributable to the amount of time and forward planning given to the question of thermal insulation.

Typical Treatment Cycle

Fig. 8 is a reproduction of an actual temperature recording made during a heat treatment cycle. It will be seen that at the commencement of the cycle the rate of temperature increase was slower than that called for by the specification; in other words, whereas the specification allowed an increase of 150° C. per hour, the chart shows that the actual rate of heating was rather slower. This was done deliberately since, on switching on, a number of things happen before the heat is actually being transferred to the girders in a manner which will give a good heat treatment throughout the cycle. The slowness of heat input resulting from passing only a very small current through the mats provided a fair amount of time for the thermal inertia of the flexible furnace, the lagging and the girder to be overcome, and reduced to an absolute minimum the possibility of major temperature gradients from one face of the girder to another, or from one side of the flanges to the other.

After running the heaters (note the uniformity of the curves) up to about 200° C., the rate of temperature rise becomes rather more rapid, but still within specification limits. Up to 650° C. it will be seen that, by and large, all the curves are well within the specified 150° C. per hour. Naturally, the ideal would be for all six curves to coincide exactly. However, slight deviations will be observed, but none of these exceed ± 50° C. The deviations do, in fact, indicate that individual control of the mats is possible. Where a mat was seen to be increasing the heat in one area too rapidly its temperature was reduced, or it was even knocked out of circuit, for a short time in order to restore uniformity of temperature over the entire weld area. Conversely, where a mat was not heating its particular area as quickly as required, the current was for a while increased slightly.

From previous remarks it will be evident that intelligent interpretation of the curves and anticipation of what was going to happen was a pre-requisite in judging the next operation required, i.e. either increasing or decreasing the current to any particular mat: at the same time it was necessary to keep in mind the overall picture of what was happening in the entire area being heated. Patience had to be exercised, since hasty alterations could have thrown the complete heat treatment cycle out of balance.

From the foregoing it will be appreciated that flexible furnaces permit the carrying out of heat treatment operations previously considered impracticable.

The Influence of Inoculation on the Number of Manganese Sulphide Particles in Cast Iron

By J. H. Gittus, B.Sc., A.I.M.

Formerly Development and Research Department Laboratory, The Mond Nickel Co., Ltd.

It was accidentally discovered that the number of manganese sulphide particles in flake-graphite iron-castings was apparently increased by inoculation. Further detailed work confirmed this and indicated also a similar, but less marked, effect of pouring temperature.

THE investigation reported here stemmed from an observation made during the examination of four castings, produced in an industrial foundry. Differences in foundry practice, composition and graphite-structure suggested that three castings had been made from inoculated metal and the fourth from uninoculated metal. Surprisingly, the latter appeared to contain by far the smallest number of manganese sulphide inclusions. This observation suggested that inoculation, as well as producing a modification to graphite morphology, also influenced the nucleation characteristics of manganese sulphide. A series of controlled laboratory experiments made to investigate this phenomenon is described, together with the results obtained, in the present paper.

Preliminary Work

For purposes which are irrelevant in the present context, four industrially-produced castings were examined. It was believed that some, but not necessarily all, had been made from iron inoculated with a silicon-manganese-zirconium inoculant (S.M.Z.). This was confirmed by analysis (Table I), which revealed that three of the castings contained zirconium, whilst the fourth did not. Metallographic examination provided supporting evidence, revealing that the zirconium-free casting was the only one which contained patches of A.S.T.M. Type "D" graphite, a structure not generally encountered in inoculated cast iron. At the same time it was observed that the uninoculated casting contained fewer and larger manganese sulphide inclusions than the other three. The minor differences in sulphur and manganese content (Table I) were not thought to be sufficient to account for this effect, which appeared rather to be attributable to inoculation.

A quantitative assessment of the effect was made by counting, at $\times 1{,}000$, the number of inclusions in each of 200 random fields, for microspecimens from each of the four castings. Each field represented about 10^{-5} sq. in. of the sample surface. The significance of any apparent difference between inclusion counts for the different castings was assessed statistically. To simplify subsequent calculations, the Chi-squared test was first employed to determine whether, as was suspected, the results conformed to the Poisson distribution. This proved to be the case for castings *B*, *C* and *D*, but not for casting *A*. The actual distributions are shown in Fig. 1 and the relevant calculation for casting *A* in Table II. In this table are compared the number of fields in which a specific number of inclusions was observed and the number which would be expected from the Poisson distribution. It is evident that the poor fit obtained in the case of casting *A* is attributable to the unexpectedly large number of fields which contained either a very small (0, 1, 2, 3) or a very large (13 and more) number of inclusions. Apparently segregation has occurred in this casting and it was deemed reasonable to suppose that, if this had not been the case, a good fit would have been obtained for casting *A* as well as for *B*, *C* and *D*. Since the average number of inclusions per field would be expected to be little influenced by such segregation, it can be used as an approximation to the variance for casting *A* as well as for *B*, *C* and *D*. (Equivalence of the average and the variance is a convenient feature of the Poisson distribution).

TABLE I.—ANALYSES OF INDUSTRIALLY-PRODUCED CASTINGS

	T.C. (%)	Si (%)	Mn (%)	S (%)	P (%)	Zr (%)
Casting A	3·24	2·21	0·90	0·159	0·11	0·004
Casting B	3·38	2·25	0·85	0·135	0·11	0·004
Casting C	3·38	2·31	0·85	0·136	0·11	0·004
Casting D	3·53	2·35	0·88	0·104	0·19	N.D.*

* Not detected.

TABLE II.—COMPARISON OF RESULTS FOR CASTING "A" (FIG. 1) WITH THE POISSON DISTRIBUTION

No. of Inclusions per Field	0 1 2 3	4	5	6	7	8	9	10	11	12	13 14 15 16 17 18 19 20 21 22 23
Expected No. of Fields (E)	12·5	15	23	28	30	27	23	17	11	7	8
Observed No. of Fields (O)	20	20	24	28	20	27	18	10	7	4	22
$\frac{(O-E)^2}{E}$	3·9	1·7	0	0	3·3	0	1·1	2·8	1·4	1·3	28

$$\sum \frac{(O-E)^2}{E} = 34$$

Highest permissible value for reasonable fit is only 30.

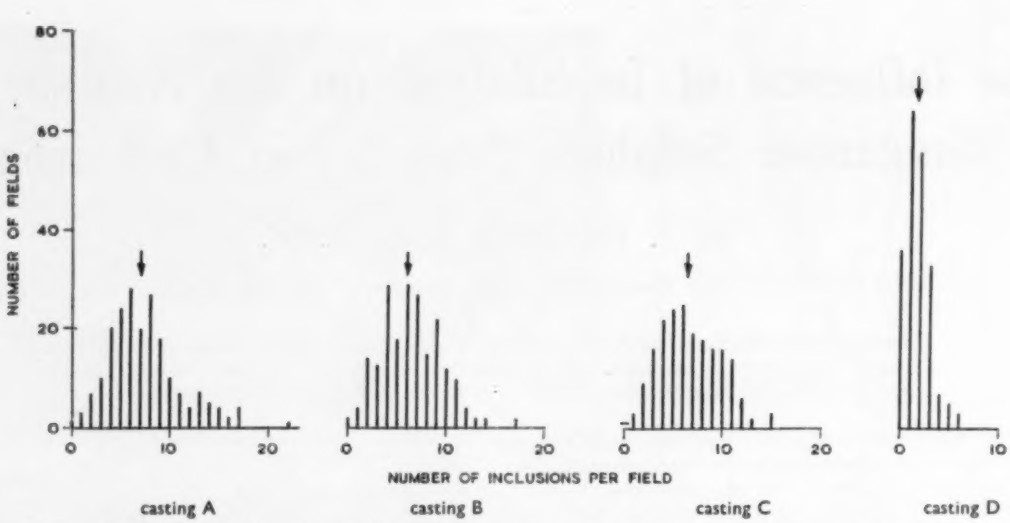


Fig 1.—Distribution of manganese sulphide inclusions in four castings : arrow indicates average.

Their variances were used to test the statistical significance of the differences between the average inclusion contents for the four castings. The calculations are detailed in Table III and the results in Table IV.

Evidently, casting *D*, which was not inoculated, contained significantly fewer manganese sulphide particles than *A*, *B* and *C*. It was decided, therefore, to attempt to repeat this observation under carefully controlled conditions in the laboratory.

Laboratory Studies

Two melts were produced in an oil-fired tilting crucible furnace. Each comprised 300 lb. of suitable pig irons and, in both cases, when the melt reached 1,480° C. it was inoculated by adding 0·625% of 80% silicon ferrosilicon to the furnace. Four taps were taken from each melt ; two immediately after inoculation and two others 30 minutes later. It is known that the inoculating effect of an addition of ferrosilicon diminishes over a period of time, so that the first two taps from each melt can be regarded as " inoculated " and the last two " uninoculated." Compositions are given in Table V.

TABLE III.—STATISTICAL ANALYSIS OF MANGANESE SULPHIDE COUNTS FOR CASTINGS A, B, C AND D

	A	B	C	D	Designation of Casting
	7·43	6·22	6·87	1·66	No. per field
A		13·65	14·30	9·09	Sums, i.e. (A + B), (A + C), (A + D)
		1·21	0·56	5·77	Differences, i.e. (A – B), (A – C), (A – D)
		0·52 0·78	0·53 0·80	0·42 0·63	$0·14\sqrt{\text{sum}}$ $0·21\sqrt{\text{sum}}$
B			13·09	7·88	Sums
			0·65	4·56	Differences
			0·51 0·76	0·39 0·59	$0·14\sqrt{\text{sum}}$ $0·21\sqrt{\text{sum}}$
C				8·53	Sum
				5·21	Difference
				0·41 0·61	$0·14\sqrt{\text{sum}}$ $0·21\sqrt{\text{sum}}$

From each tap from both melts two green-sand-moulded K bars and two dry-sand-moulded K bars were cast at 1,440° C., 1,360° C. and 1,270° C. The K bar was chosen since it is known that this casting exhibits porosity. The extent of this porosity would, it was thought, be influenced by inoculation and pouring temperature to an extent which would be reflected in the inclusion counts.

The inclusion counts were made in the manner previously described, with the results shown as Fig. 2.

TABLE IV.—SIGNIFICANCE OF DIFFERENCES BETWEEN MANGANESE SULPHIDE COUNTS FOR CASTINGS A, B, C AND D (*cf* TABLE III)

$\geqslant$ = 1% level,
i.e. $(A - B) > 0·21\sqrt{A + B}$

$>$ = 5% level,
i.e. $(A - B) > 0·14\sqrt{A + B}$

	A	B	W	D
A		$A \geqslant B$	$A > C$	$A \geqslant D$
B			$B < C$	$B \geqslant D$
C				$C \geqslant D$

i.e. $A > C > B \geqslant D$.

TABLE V.—ANALYSES OF EXPERIMENTAL MELTS

Melt No.	Tap No.	Composition (%) T.C.	Si	Mn	S	P
1	1	3·04	1·85	0·51	0·128	0·48
	2		1·85	0·54		
	3	3·01	1·76	0·54	0·129	0·48
	4		1·77	0·56		
2	1	2·59	1·84	0·49	0·146	0·46
	2		1·94	0·49		
	3		1·76	0·50	0·139	0·48
	4		1·81	0·48		

TABLE VI.—COMPARISON WITH THE POISSON DISTRIBUTION OF RESULTS FOR SPECIMENS FROM MELT 2, INOCULATED AND POURED AT 1,270° C.

No. of Inclusions per Field	0	1	2	3	4	5	6	7 8 9 10 11
E	4	13	25	27	21	13	7	4·5
O	7	14	23	18	11	12	8	7
$\frac{(O-E)^2}{E}$	1	0	0·2	3	5	0	0·2	1·5

$$\sum \frac{(O-E)^2}{E} = 11$$

Highest permissible value for good fit is 27.

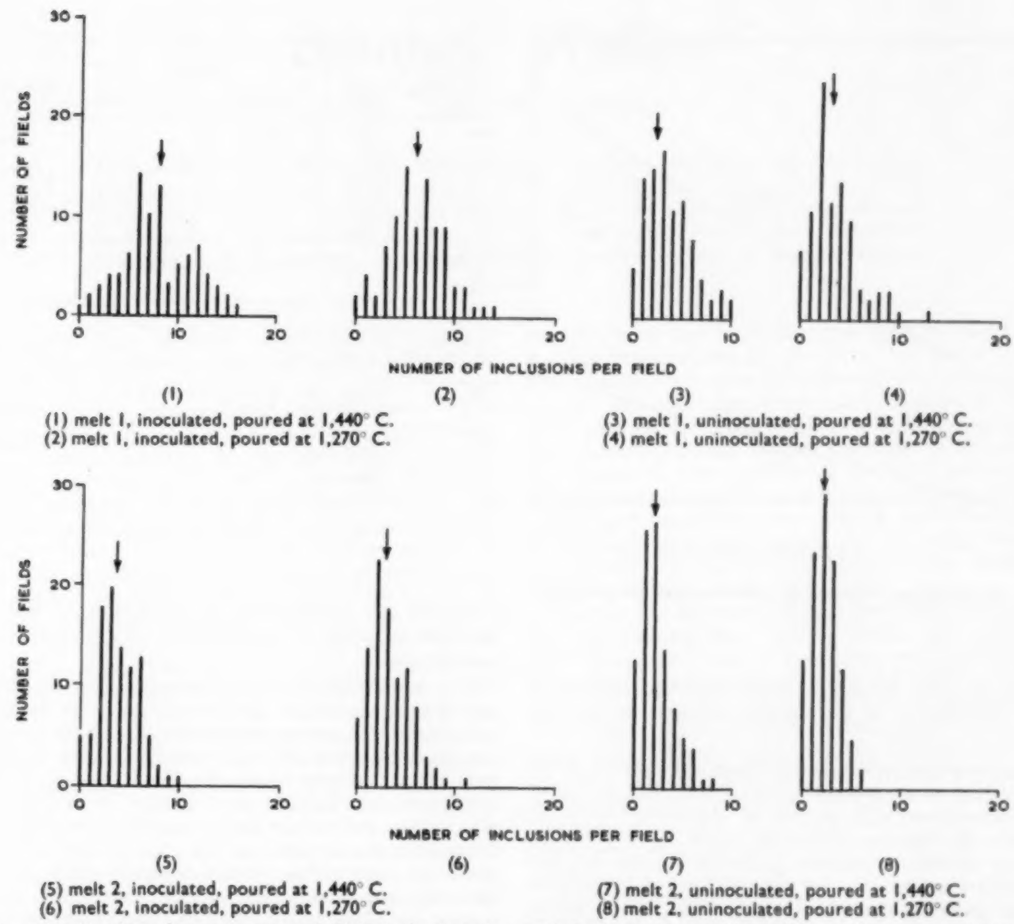


Fig. 2.—Distribution of manganese sulphide inclusions in castings from two melts, with varying pouring temperatures, and with and without inoculation : arrow indicates average.

In this case only 100 fields were counted for each specimen. The Chi-square test was applied and confirmed that the results generally conformed to the Poisson distribution. An example of this calculation is shown in Table VI. Table VII gives the mean number of manganese sulphide particles per field for each of the specimens. The significance of any apparent differences between these means was computed from their variances with the results shown in Tables VIII, IX and X. The effect of inoculation upon the manganese sulphide count is confirmed by Table VIII, whilst Table IX reveals a slight effect of pouring temperature : castings poured at the highest temperature tend to contain the most manganese sulphide particles. Table X shows that in every case specimens from Melt No. 1 contained more inclusions than equivalent specimens from Melt No. 2.

TABLE VII—MEAN NUMBER OF MANGANESE SULPHIDE PARTICLES PER FIELD FOR EXPERIMENTAL CASTINGS (*cf.* FIG. 2)

	Melt 1		Melt 2	
Temperature (°C.)	1,440	1,270	1,440	1,270
Inoculated	(1) 8·08	(2) 5·96	(3) 3·79	(4) 3·19
Uninoculated	(5) 3·55	(6) 3·46	(7) 2·20	(8) 2·20

TABLE VIII.—EFFECT OF INOCULATION ON MANGANESE SULPHIDE COUNT

Entries from Table VII Employed	(1) and (5)	(2) and (6)	(3) and (7)	(4) and (8)
Sum	11·63	9·42	5·99	5·30
$0 \cdot 3\sqrt{\text{sum}}$	1·06	0·92	0·73	0·69
Difference	4·53	2·50	1·59	0·99
Difference Significant	1>5	2>6	3>7	4>8

TABLE IX.—EFFECT OF POURING TEMPERATURE ON MANGANESE SULPHIDE COUNT

Entries from Table VII Employed	(1) and (2)	(3) and (4)	(5) and (6)	(7) and (8)
Sum	14·04	6·98	7·01	4·40
$0 \cdot 3\sqrt{\text{sum}}$	1·13	0·79	0·79	0·63
Difference	2·12	0·60	0·09	0·00
Difference Significant	1>2	Not	Not	Not

TABLE X.—EFFECT OF MELT ON MANGANESE SULPHIDE COUNT

Entries from Table VII Employed	(1) and (3)	(2) and (4)	(5) and (7)	(6) and (8)
Sum	11·87	9·15	5·15	5·66
$0 \cdot 3\sqrt{\text{sum}}$	1·02	0·91	0·72	0·71
Difference	4·29	2·77	1·35	1·26
Difference Significant	1>3	2>4	5>7	6>8

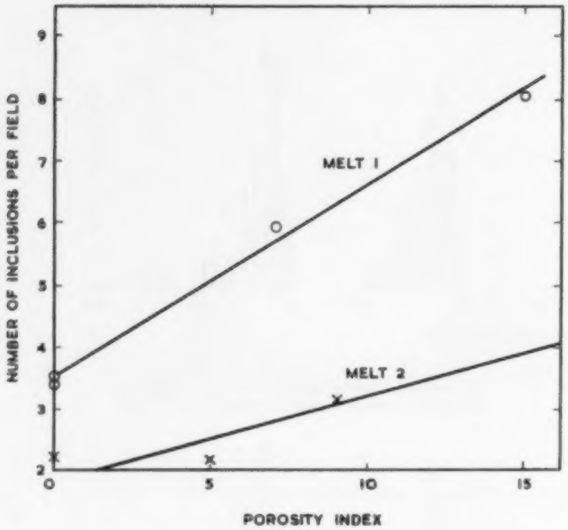


Fig. 3.—Association of porosity and manganese sulphide count.

The only known difference which can be adduced to account for this is in the carbon contents of the two melts.

As had been expected, the castings were porous to an extent which was estimated by visual inspection of fractured surfaces, with the results shown in Tables XI and XII. In Fig. 3 a " porosity index " computed by summing the relevant entries in Tables XI and XII has been plotted against the average number of manganese sulphide particles per field, suggesting that insofar as it indicates the degree of nucleation in the melt, a manganese sulphide count can be employed as an index of porosity.

Discussion

Inoculation increases the number of eutectic cells in flake graphite cast iron. Why it should have this effect is not known, although various suggestions have been made. Examination of specimens occasionally reveals a graphite flake apparently growing from a manganese sulphide inclusion, and this had led some investigators to suppose that such inclusions nucleate the eutectic. The present work might appear to support this view, since it has shown that inoculation increases the number of manganese sulphide particles. The difficult practical task of proving that some or all of the manganese sulphide particles observed in the present investigation were nuclei for eutectic cells has not been attempted, nor is it likely that such an attempt would yield a very positive and satisfactory conclusion. Moreover, even if the above explanation for the inoculating effect of ferrosilicon is accepted, it can only apply to cast iron which contains manganese sulphide particles. Magnesium-treated cast iron would, therefore, be an exception, since although it can be inoculated with ferrosilicon, it contains very few, if any, manganese sulphide inclusions. In any case, such a theory would necessarily be incomplete since, although it might explain why the number of eutectic cells is

TABLE XI—POROSITY IN CASTINGS FROM MELT 1

Pouring Temperature (°C.)	Mould Type	Condition: Inoculated		Uninoculated		Type of Defect
1440	Green	2 2	2 1			
	Dry	2 2	2 2			Porosity
1360	Green	2 2	2 2			1 = Porous
	Dry	2 1	2 1			2 = Very porous
1270	Green	1 1	1 1			
	Dry	2 1				
Tap Number		1	2	3	4	

TABLE XII.—POROSITY IN CASTINGS FROM MELT 2

Pouring Temperature (°C.)	Mould Type	Condition: Inoculated		Uninoculated		Type of Defect
1,440	Green	2 2	2 1	1 1	1 1	
	Dry	1 2	2 1			Porosity
1,360	Green	1 2	2 1	2		1 = Porous
	Dry	1	1			2 = Very Porous
1,270	Green	2 2	2 2			
	Dry		1			
Tap Number	.. ..	1	2	3	4	

increased by inoculation, it does not explain why inoculation increases the number of manganese sulphide particles.

It is more reasonable to assume that the two effects of inoculation, upon inclusion count and upon the number of eutectic cells, are unconnected. This in its turn might suggest a universal effect of ferrosilicon upon the nucleation of all phases separating from the melt during solidification. This is not the case, however, and in other work the author has found that inoculation with ferrosilicon has no influence upon the number of primary austenite crystallites which separate from a hypo-eutectic melt of cast iron. Again, inoculation does not appear to alter the nucleation characteristics of the metastable eutectic in white-iron castings.

Conclusions

Variations in the degree of inoculation of a cast iron melt, produced by changes in pouring temperature or a late addition of ferrosilicon, are associated with a change in the number of manganese sulphide particles. Some correlation between the extent of porosity and manganese sulphide count exists. It is not thought that the increase in the number of eutectic cells produced by inoculation is a direct consequence of the accompanying increase in inclusion count.

MORGAN REFRACTORIES, LTD., of Neston, Cheshire, a member of the Morgan Crucible group of companies, has sold a substantial quantity of MR2 super duty firebricks to line part of the stack of an Australian blast furnace. The order is being shipped to The Broken Hill Proprietary Co., Ltd., and is worth approximately £25,000.

CONTRACTS valued at £317,000 have been obtained by the Motor and Control Gear Division of Associated Electrical Industries, Ltd., for over two hundred direct current motors which will be used for driving heavy duty cranes in the new Spencer Works near Newport, Monmouthshire of Richard Thomas and Baldwins, Ltd.

Samuel Walker

By Eric N. Simons

In these days of large industrial groups, it is not so easy to start from small beginnings and build up a large and prosperous family business as it was in years gone by. Many present day industrial enterprises had their beginnings in the eighteenth century, although for every success in those early days there were probably many failures. One of the former is the subject of this article: in company with his brothers he built up a business and a fortune.

TO avoid falling into the error made by so many historians, let it be established in this article at the outset that Samuel Walker was but one partner in a firm of ironfounders at Kimberworth, near Rotherham, who was brave, able, and tenacious enough to build up a business and a fortune by "turning iron into steel," as the crude phraseology of the time would have put it. The other original partners were his two brothers, and there may have been at least one other partner.

Samuel Walker was the son of Joseph Walker of Stubbing House, Ecclesfield, a nailer, and of Ann Walker of Ecclesfield; his father died in 1729 and his mother in 1741. She left a little cottage property. In addition, there were three daughters, at least one of whom married. Samuel himself was born in 1715, and there are various stories of his early years that it would be difficult at this stage to check. One records that he constructed to his own designs, and satisfactorily traded in, sundials. He married in 1741, and for about four years became a schoolteacher, for which he received the magnificent remuneration of 24s. 6d., but whether this was for a week or a term is not clear. He kept a journal in which he set down some of the events of his life, but, as usual with these journals, the record is not beyond reproach, some of the entries being designed to read as favourably as possible for the diarist.

It was in 1745 that Samuel left the teaching profession, and by this time he had built himself a house. He considered he had settled down for good, but in 1749, by which time he and his brother had already begun to manufacture iron castings, he left Grenoside, where he had established himself, and went to Masborough. There are conflicting versions of his reasons for doing this, one being that he was at odds with a Grenoside family called Tingle. His own excuse is that he was too far from a navigable river, but this explanation is unconvincing to historians.

What he was doing between 1745 and 1749 is not known, but his brother Aaron was already producing iron castings in 1745 at the rate of 39 tons a year. In 1746, 63½ tons were produced, the business as then established being valued at £400: it is believed that Samuel was assisting his brother on the commercial side. It was in the November of 1749 that Samuel removed to Masborough, and the probability is that previously Aaron had rented a works on the Effingham estate until that date. The Masborough furnace appears to have been built in 1748, as Samuel records its construction during this year by himself and Booth, as well as that of a house (and barn) in which he took up residence.

The business started by Aaron Walker was developed with Samuel's help during the next five years, by which time its value had increased from £600 to £4,800. The castings produced during the period totalled 1,579 tons. The brothers even then paid themselves extremely small salaries, said not to have exceeded ten shillings a week. They paid no dividends and distributed no capital: on the contrary, Samuel Walker put £400 of his own into the business in 1754, and Mr. H. G. Baker has suggested that there may have been someone with capital in the background, whose identity has not come down to us. As the founders were relatively poor men, and there was no such thing as limited liability, they must have had a backer, at least in their early years.

The iron the Walkers cast was first melted in pots, but this was unsuccessful. Aaron Walker had started his little business in 1741 at Grenoside, and with Samuel's help had built an air furnace in an old nailer's smithy on the back side of the cottage Samuel had inherited from his mother. While teaching, Samuel would possibly have spent some of his spare time in helping, and work gradually became more plentiful. At this period Aaron was paying himself only four shillings a week, which was all he had to live on. They took on a few hands as trade increased, getting their men from among the nailers and agricultural workers of the district.

Walker's journals give a detailed account of the progress of the works, and it is clear from these that the eldest brother, Jonathan Walker, first became a partner in 1746, when he invested £100 in the business. He lived at Grenoside until 1761 and did not come to Masborough to live until that year, when the house he was building had been completed. He is said to have taken charge of the farms, teams, roads, etc., used by the business.

Growth of the Enterprise

The third partner was John Crawshaw, who put in £50 in 1746 and £400 in 1754. Both he and Jonathan were sleeping rather than active partners, and it was only when the works were extended in 1761 that he, like Jonathan Walker, came to live in Masborough. He did not become a full partner until after Samuel's death. In 1854 the yearly output of the works had risen to 318 tons, and the valuation now attained the record figure of £5,600. This soon increased to £8,500, with an output of 284¼ tons of castings, and some workshops had now been built outside the Masborough Street and Dun Close areas.

By the time the year 1760 was reached, the firm was making 432¾ tons of castings in a single year, and after taking out a dividend of £140, the valuation of the net stock was £11,000. It would be tedious to give year by year the continued growth of the works. It is sufficient to say that Samuel Walker died an extremely rich man for

his period, while on 1st May, 1781, the supposed value of the capital was £110,000, which was expected to reach the figure of £128,000 by 1st May, 1782, and after £28,000 had been divided, the capital would still remain at £100,000. 1899 tons of castings were made.

It was on the 12th May, 1782, that Samuel Walker died, aged 67 years. Jonathan had pre-deceased him in 1778 and Aaron in 1777. The partners at the time of Samuel's death were Joshua Walker, Joseph Walker, Thomas Walker, Jonathan Walker (junior), John Walker, and John Crawshay or Crawshaw.

Four years before his death, Samuel founded a lead company, providing most of the capital. His sons went into this business, which in 1817 had assets amounting to over £450,000, and today this same establishment carries on trade under the well-known name of Walkers, Parker & Co., Ltd. Samuel not only owned two thirds of his own firm, but also an unknown share of a steel firm operated by himself, Booth and Crawshaw. Booth witnessed his will, by which he left all his shares to his four sons, £7,000 to each of his two daughters and annuities to his wife and a third daughter, Sarah.

It must be borne in mind that Samuel Walker & Co., the parent firm, never made steel. Such steel-making as went on was done by Walker, Booth and Crawshaw, and by Booth and Walker. Booth never had any shares in Samuel Walker & Co. The Crawshays or Crawshaws are believed to have moved to South Wales.

Legend Discredited

This is the point at which may fittingly be recalled, if only as a legend with no foundation in fact, the story that used to be told of Samuel Walker to every newcomer to the Sheffield steel industry, as it was told to me nearly fifty years ago. Most readers will recall that the first satisfactory crucible cast steel was melted by Benjamin Huntsman in his works at Attercliffe, near Sheffield. Huntsman, of course, regarded his method of making steel as highly secret, and all his men were sworn to secrecy. One night, the story goes, an old tramp presented himself at the works gates, craving to be allowed to shelter from the bitter cold outside and sleep by the warmth of the furnaces. Taking pity on his wretched condition, the kind-hearted workmen allowed him to doss down near where the crucible pots were being heated. The tramp is said to have slept with one eye open, kept careful watch, and departed next morning with Huntsman's secret inside his skull.

Now in point of fact this ingenious and romantic tale has been completely disproved by Mr. Hulme in his well-documented and authentic account of the life of Benjamin Huntsman. There was, in truth, a leak, and after a time the method of making crucible steel was disseminated among competing steel manufacturers; but the leakage was not through the machination of an unscrupulous and histrionic Samuel Walker. There was a lawsuit between Huntsman and some of his competitors and it is said that a man of law allowed his tongue to prattle in conversation in London. The litigants opposed to Huntsman pricked up their ears, and were put right on to the track of efficient tool steel manufacture. A historical work published as recently as 1948 still gives a certain amount of credence to the first fantastic story, and it is as well that the truth should be put once again on record.

When Samuel Walker died, the works covered various sites in the Kimberworth, Masborough and Rotherham areas: the main works were, of course, after 1749, in Masborough. There was a forge at Thrybergh (then spelled Thribro'); another forge at Rotherham; a furnace at what is now, and was then, known as the Holmes; a boring house at the bottom of Kettle Croft; and a furnace at Yellands.

The Human Touch

The Walker records contain many human touches. For example, they record the death in 1774 of Thomas Whiteley "one of our first and principal clerks, but a sad specimen of the instability of human nature." One wonders what Mr. Whiteley's instability had led him to do. In 1764 they built a large "shop for frying pan makers." They could be "surprised" by the revelation of their accounts that they were better off than they thought they were. They built a new henhouse in 1773 and a tallow house in 1774. They lost a good deal of money in "the wood trade," and in 1776 built "a new vault or burying house." They made guns and built a fire engine,* as well as a new chapel. The fire engine was of the atmospheric type, with a cylinder 72 in. bore and a stroke of 6 ft. (I believe the engine house is still to be seen.) It appears, from a note of 1778, that the fire engine did not answer very well. A new one was built in 1779: "this is a very heavy job." It had a single acting 40 in. diameter steam cylinder to "work up and down," with a joint stroke of 8 ft., and a 50 in. blowing cylinder. The beam was of wood, with the centres of the cylinders set at 22 ft. The steam chest and valve nozzles and the brass eduction pipe were supplied by Boulton and Watt: everything else was made at the Walker works.

The hall occupied by Samuel Walker was evidently a charge upon the company's resources, for in 1782 there is a record that "made various alterations and improvements at the Hall to sute Mr. S. W." It is true the note adds "at his cost"; but one wonders if this was not put in to cover up expenditure not strictly within the firm's rights.

The Crawshaw or Crawshay mentioned earlier in these notes had married Samuel's half-sister, Mary. He had failed like Aaron Walker, to make iron castings successfully, and in 1743 he was down to being an ordinary foundryman at a shilling a day. He managed somehow to get the capital to put into the business, and at one time there was friction between him and Jonathan Walker, but this blew over "to the credit of all parties, brotherly love being re-established." Nevertheless, despite this reconciliation, the Walkers got rid of the Crawshaws as managers in the following year, or else the Crawshaws went of their own accord—the record is ambiguous. It is said that John Crawshaw senior was responsible for the management of the blast furnace, and his son dealt with the foundry orders, the packing and delivery of the goods produced, and the cash book.

The detailed information on which most of this article is based was originally compiled by Mr. H. G. Baker and presented in a lecture to the Society for the Preservation of Old Sheffield Tools. Mr. Baker's account is, however, vastly longer than this summary and could not have been accommodated in this short space. Any reader wishing to read the entire lecture should apply to the Editor of *The Edgar Allen News*, Imperial Steel Works, Sheffield, in which the lecture was printed in full many years ago.

* The term "fire engine" refers, not to fire-fighting equipment, but to a machine for blowing the three furnaces.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NEWS AND ANNOUNCEMENTS

Painting of Metal-Sprayed Structural Steelwork

DURING the last twenty years the use of sprayed metal coatings of aluminium or zinc to protect structural steelwork has grown in importance, and this method of protection is now frequently specified by consulting engineers for structures to be erected both at home and abroad. So far as is known, satisfactory results have been obtained in the majority of cases, but recently there have been several instances of premature failure of the protective scheme in important structures treated in this way.

These observations have led to doubts regarding the merits of sprayed metal coatings beneath paint for the the protection of structural steel. It is, therefore, important to clarify the position and lay down the conditions under which properly chosen and well applied composite protective schemes of sprayed metal coatings and paint can be relied on to protect steel satisfactorily for specified periods.

The British Iron and Steel Research Association, through its Corrosion Advice Bureau, is taking the initiative in doing this, by organising a collaborative investigation with the financial support of all who may be interested in the subject. Direct approaches have been made to the various trade associations and professional bodies concerned, but any others, including individual firms, who would like to participate are invited to write to the Secretary, Corrosion Advice Bureau, B.I.S.R.A., 140 Battersea Park Road, London, S.W.11. It is envisaged that a total fund of £5,000 will suffice for the purpose of the research, and the subscriptions already made or promised render it probable that this amount will be raised.

The object will not be to compare a large number of painting schemes on a competitive basis, but to show how good results can be achieved by following the advice given by experts based on present knowledge. To this end the test programme will be drawn up by an Advisory Research Panel, appointed at a general meeting to which all subscribers will be invited, and at which they will be free to make suggestions. The work will be carried out by the Corrosion Advice Bureau, and progress reports will be issued at appropriate intervals to subscribers six months in advance of open publication.

Oxygen for Italian Steelmaking

AIR PRODUCTS (Great Britain) Ltd., announce that it is building a 380 tons per day oxygen plant at the O. Sinigaglia steel works of Cornigliano, Genoa, Italy. The plant, the first to be built for an Italian steel company, will consist of two generating units each capable of producing 190 tons per day of oxygen, and storage for 560 tons of liquid oxygen, and 420,000 cu. ft. of high pressure gaseous oxygen will also be included. Most of the plant's oxygen production will be in gaseous form, but a substantial amount of liquid will also be produced and stored as an independent supply. Nitrogen of 99·8% purity will also be produced for annealing applications. The oxygen plants are of the "split cycle" design, an advance in oxygen production technology developed by Air Products to provide economically a high level of liquid oxygen production for storage while generating the major portion in gaseous form.

Cornigliano has experimented for several years in the intensive use of oxygen in the open hearth furnaces and has achieved remarkable increases in output: the introduction of oxygen is expected to increase the output of Cornigliano's six open hearth furnaces from 1,102,300 to 2,094,400 tons per year. Oxygen is added during combustion to increase the heat input to the furnace and is then injected through roof lances during the refining phase to speed up the removal of carbon and other impurities.

Induction Furnace Agreement

AN agreement signed between The General Electric Co., Ltd., of England and The British-Geco Engineering Co., Ltd., of Edenbridge, Kent, covers the design, manufacture and sale of induction furnaces, such that the resources and expert knowledge of the two companies in all matters relating to induction heating are combined.

Both companies have extensive facilities for research and development work covering all aspects of induction heating, and are able to undertake the design and manufacture of all types of induction heating plants for ferrous and non-ferrous metals. The types include melting equipment, billet heating equipment, soldering and brazing machines, local heat treatment plant and stress-relieving equipment. Enquiries for induction heating plant covered by the agreement and requests for information should be addressed to the Furnace Department, The General Electric Co., Ltd., Erith, Kent.

Comatic Automatic Welding

ROCKWELD, LTD., will shortly introduce into this country the Comatic automatic welding process, which has been developed to overcome the difficulties of fast vertical welding of relatively thin plates in mild and low alloy steels. It will, in fact, weld plates down to ½ in. thick. The principle of operation is that the wire and parent plate are melted by an arc, the weld being protected by CO_2 gas. The molten weld metal is contained by water-cooled copper shoes, located on opposite faces of the plate being welded and traversing upwards as welding proceeds.

The machine consists of a vertical frame with two tracks which carry the welding head carriage. This carriage is equipped with a wire feed roll drive, a wire drum, a vertical traverse drive mechanism, an adjustable wire guide oscillation device, and fixtures for carrying the copper shoes. Controls and meters are incorporated in a cabinet attached on top of the carriage. The column, which is fitted with a lifting lug at the top, clamps directly onto the workpiece—the workpiece, in fact, supports the frame. The machine can be craned into an appropriate position on the workpiece. The structure is as light as possible consistent with rigidity.

In operation, the CO_2 arc gives the necessary side wall penetration with a small gap. When thin plates are

being welded the wire is fed in centrally between the plates; for heavier plates the wire is made to oscillate across the thickness of the material. High operational speeds are possible. For example, with ¾ in. thick plate a speed of 15 ft. an hour is possible. It is claimed that high-quality weld metal and perfect radiographs are obtained, and that impact properties are good.

The power requirement is a standard, drooping characteristic, welding generator, or transformer/rectifier equipment of similar characteristic, fitted with current control only, arc voltage control being fitted to the welding head. The welding generator or transformer/rectifier should be rated at 750 A. for continuous duty.

New British Science Export

ORDERS are being received at the rate of one a month —£200,000 a year—from home and overseas for the X-ray scanning microanalyser developed by the Tube Investments Research Laboratories in collaboration with the Cavendish Laboratory at Cambridge, and now being manufactured and marketed by the Cambridge Instrument Co., Ltd. Deliveries have begun, and three instruments will be exported to the United States during this year.

This specialised instrument provides a qualitative and quantitative metallurgical analysis of a sample by irradiating and scanning the sample under investigation with a fine beam of electrons, and analysing the resulting emission of X-rays. The X-ray image is displayed on one of two cathode ray tubes. The other tube simultaneously displays a reflection electron image of the same area. Thus a direct visual comparison between the surface topography of the specimen and the distribution of a selected element can easily be made. The microanalyser has wide and growing research and industrial applications.

Griffin & George Acquire R. & J. Beck

GRIFFIN & GEORGE, LTD. have purchased the whole share capital of R. & J. Beck, Ltd., one of the oldest-established firms of optical instrument manufacturers in Britain. It is the intention of Griffin & George, Ltd. to retain the individuality of Beck's as a separate entity, but, at the same time, it is anticipated that the growth and future prosperity of that company will benefit from an association with the larger organisation. Griffin & George, Ltd. have undertaken the continued employment and future treatment of existing staff, and the name of the business will remain unchanged. The present board, consisting of Messrs. C. J. Beck, S. Borthwick, G. E. Fowler and H. W. Morgan, will remain in office and be joined, in due course, by Messrs. M. Lyth, H. C. Mayer, R. C. Palmer and F. A. Renn as additional directors representing Griffin & George, Ltd.

Bonding Dissimilar Metals

THE firm of Ladd & Little, Inc., of Huntington Station, Long Island, New York, composed of former technical and administrative executives of the Al-Fin Division of Fairchild Engine and Airplane Corporation, offers, on a consulting basis, techniques for metallurgically bonding aluminium or magnesium to steel, iron, nickel, titanium, etc. Services include product design and production "know-how." Typical examples of their experience in design, development, and production techniques include aluminium-bottomed stainless steel cooking utensils made under their direction by concerns in Germany, Switzerland, England, Australia, Sweden, Italy, the United States and Canada; armoured ring band pistons which are used throughout the world in heavy-duty engines; and aluminium brake drums with bonded-in cast iron braking surfaces as used by Mercedes on all models since 1953 and by B.M.W., as well as by Buick and Pontiac in the U.S. Ladd & Little also engages in technological licensing internationally offering American processes and products and trade secret "know-how" abroad and developments from abroad in the U.S.

Metal Finishing Supplies.

UNDER the terms of agreements between Modern Electrolytic Patents and Processes, Ltd., on the one hand, and W. Canning, Ltd., and R. Cruikshank, Ltd., on the other, all three firms will supply the complete range of solutions, standard plants and specially designed equipment for electropolishing offered by M.E.P.P., and Canning and Cruikshank will design and install automatic machines. M.E.P.P. are exclusive licensees for the processes developed by Battelle Institute (U.S.A.), the Jacquet-Hispano Suiza Group (France) and Elektrolyse Gesellschaft m.b.H (Germany), and are the only organisation in the U.K. offering a complete range of plants and chemicals for electropolishing ferrous and non-ferrous alloys.

Vacuum Melting Furnace Order

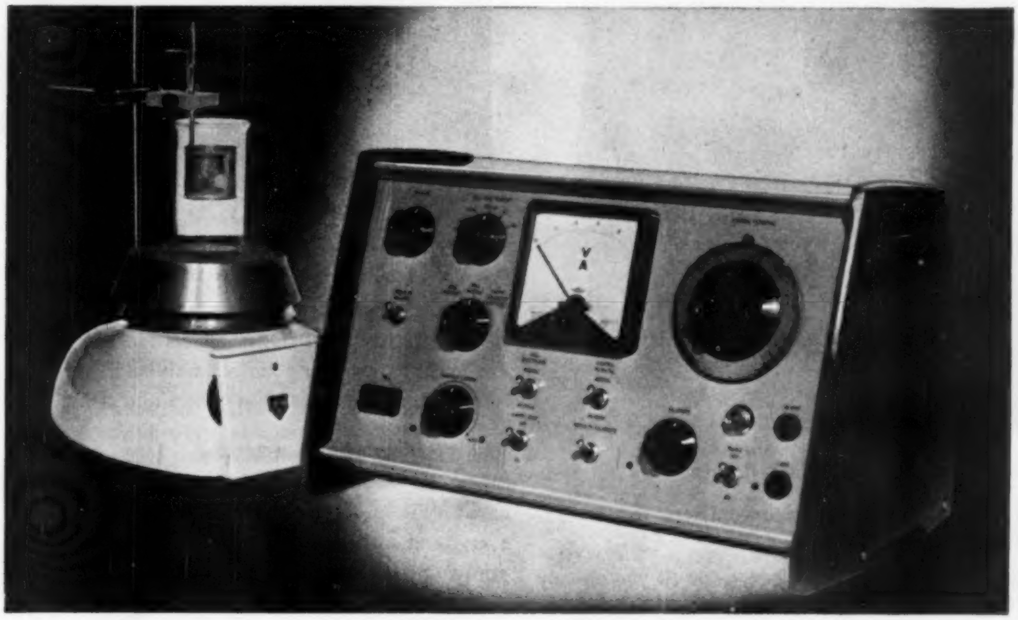
THE GENERAL ELECTRIC CO., LTD., in association with Vacuum Industrial Applications Ltd., and the British Geco Engineering Co., has secured an order, approaching £100,000 in value, from Jessop-Saville, Ltd., for the supply of an induction melting furnace of 1 ton capacity. This is believed to be the largest furnace of its type being manufactured in this country, and it is scheduled for installation in the company's Brightside Works, Sheffield, by the end of the year. The furnace, which will operate at 1,700° C., is designed for semi-continuous operation and has provision for casting under vacuum. Bulk charging and alloy addition can also be effected without breaking the vacuum. Power is to be supplied to the furnace at two frequencies, one of which will be used for heating, and the other for stirring the molten metal.

Largest Tonnage Oxygen Plant

A CONTRACT to build and operate the biggest tonnage oxygen plant serving the iron and steel industry in Western Europe has been placed with British Oxygen Gases, Ltd., by The Steel Company of Wales, Ltd. The plant, which is to be installed at the Margam Works, will have a capacity of 566 tons of oxygen per day, and is scheduled to come into operation by January, 1962. It will also be the first tonnage oxygen plant for blast furnace air enrichment in Western Europe. Costing well over £1 million, the plant will enrich by 4% a total blast volume of 200,000 cu. ft. of air a minute. Final oxygen content of the enriched blast will thus be 25%. The higher oxygen content will give a substantial increase in the iron produced by the furnaces. In addition to increasing output from existing capacity, this technique will lead to greater efficiency in the blast furnace process.

A 1654
Wadsworth Controlled Potential Electro-Depositor

ELECTRO-DEPOSITION has long been recognised as an analytical and separative technique for solutions containing metallic ions. The method may be applied where the ionic concentrations of the metals present in solution vary widely, separation being best achieved where the potential of the working electrode relative to the solution is controlled, using a reference electrode as described



independently by Sand & Fischer. Manual control of the electrode potential, although possible, is tedious and time consuming, with the result that automatic control circuits have been developed by a number of workers.

The Southern Analytical controlled potential electro-depositor is based upon a design due to N. J. Wadsworth of R.A.E., Farnborough, and is intended primarily for use with platinum electrodes. The circuit is fully transistorised in the interests of compactness and reliability and is capable of supplying a maximum controlled current of 10 amperes to the electrolysis cell. In operation, the required cathode potential is preset upon a built-in high grade potentiometer. Any error between the preset potential and that of a reference half-cell (e.g. saturated calomel), mounted immediately adjacent to the cathode, is applied to an amplifier which controls the current passing through the cell in such a sense that the potential error tends towards zero.

In order to ensure that thermal drift in the control amplifier is held at a very low level, a water-cooled heat sink is employed to maintain the transistors at a substantially constant temperature. The accuracy of control attained may be judged from the fact that the incremental error in electrode potential as a function of cell current has a mean value of 1.6 millivolts/ampere; thus, when the electrolysis current has fallen to the low levels obtaining towards the end of a deposition, extremely close control is established. It is noteworthy that the potential defined by the built-in potentiometer cannot be exceeded as cell current cuts off at zero potential error.

The apparatus is supplied complete with leads for connection to the user's own electrode assembly. If desired however, suitable standard accessory equipment can be provided.

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RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Quenzine Quench Oils

QUENCHING oils containing Quenzine—a formulation of wetting oils and other ingredients developed in the U.S.A. by Aldridge Industrial Oils, Inc.—are now being made in this country and marketed by the Electric Resistance Furnace Co., Ltd. The oils are claimed to give greater hardness to oil hardening steels, and to give a deeper case more rapidly and with minimum distortion, oxidation and sludging. In the initial and intermediate temperature range they have very much increased cooling power, but below 370° C. the cooling rate reduces rapidly to permit gradual transition to martensite, thus combining maximum hardness with minimum distortion, strain and cracking. They are particularly economical to use, showing little, if any, deterioration over long periods of hard usage, and, due to their light viscosity, draining more freely from the work. Quenzine, once mixed, becomes an integral part of the quench oil and will not separate. It has no preferential dragout, it contains no soaps or fats, and it is not affected by filters. Quenzine does not hold water but allows moisture to settle and to be drained off from the bottom of the tank.

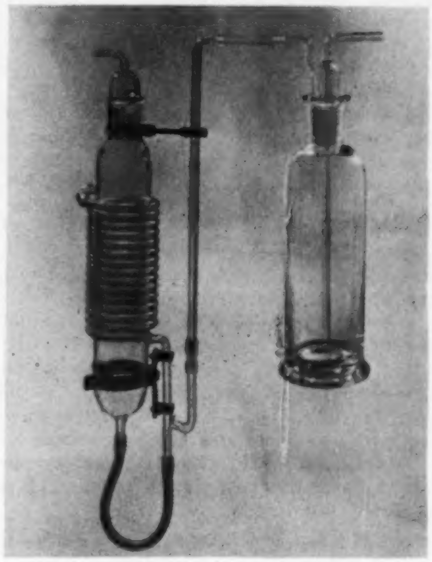
Quenzine quench oils are supplied in three grades, K9 for use at 130°–180° F., K150 for use at 225°–300° F., and K300 for marquenching at 325°–400° F. K9 gives maximum hardness in tools, cutlery, bearings and other parts heated in any medium, including salts and cyanide. K150 is recommended when absence of distortion and cracking are the main considerations. This oil, though producing hardness to a degree and depth comparable with K9 causes no more distortion and cracking than oils and salts used at 350°–400° F. At 100° F., K9 and K150 have viscosities of 90 and 190 S.U.S., respectively. K300 has a viscosity of 90 S.U.S. at 210° F.

Electric Resistance Furnace Co., Ltd., Netherby, Queen's Road, Weybridge, Surrey.

Removal of Oxygen from Gases

THE Nilox gas purification system developed by Southern Instruments, Ltd., enables the laboratory worker to obtain on the turn of a tap a continuous stream of hydrogen, nitrogen, argon, etc., completely freed of the oxygen normally contaminating these gases as supplied in cylinders. The apparatus consists of a pre-purifier containing an organic reagent which absorbs the major part of the oxygen: this reagent is then regenerated in contact with a bed of lead wool. The gas then passes to a scrubber which finishes off the purification. This scrubber is designed for highly efficient gas-liquid exchanges, the primary absorbent being a chromium salt which is oxidised in the process and subsequently reduced back by contact with amalgamated zinc.

The gas stream may flow at any rate up to 20 litres per hour and the reagents need only be renewed at long intervals. The two purifiers, which are mounted on a special stand, will also retain impurities such as carbon dioxide, hydrogen sulphide, sulphur dioxide, chlorine, ammonia, and amines. The apparatus is a great time saver for organic synthesis, carrier gas methods, glove box work, polarography and many other operations requiring inert atmospheres.



Southern Instruments, Ltd., Frimley Road, Camberley, Surrey.

Bright Platinum Plating

THE development of platinum plating has been limited due to the difficulties associated with conventional plating baths. Johnson Matthey have now made available a stable platinum plating solution from which bright, heavy and coherent deposits may be obtained. This bath, known as DNS platinum plating solution, is based on the complex sulphato-dinitrito-platinous acid ($H_2Pt(NO_2)_2SO_4$), and patent applications covering electrolytes of this type have been filed in a number of countries. The bath is acidic, and may therefore be used successfully on electrical components and on printed circuits. Platinum from DNS solution can be deposited directly on to copper, brass, silver, nickel, aluminium and titanium. For deposition on tin, zinc, cadmium or steel, an undercoat of silver or nickel is necessary.

The exceptional resistance to corrosion characteristic of platinum, coupled with its ease of deposition, assure the electrodepositor of a wide variety of industrial uses. Deposits from the new bath are exceptionally bright and lustrous at all thicknesses, and no polishing is required. Electrographic tests have shown no evidence of porosity in deposits up to 0·001 in. in thickness on polished copper. Above this thickness some slight evidence of

cracking may be observed. Microhardness tests on deposits give values of 400–450 V.P.N.

The DNS platinum plating solution is supplied as a concentrate containing 10 g. platinum per 100 ml. of solution. For general use this should be diluted to 5 g. platinum per litre. Glass, earthenware or plastic tanks should be used. The character of the deposits remains unchanged in the temperature range 30°–70° C., but the recommended operating temperature is 50° C.

At a current density of 5 A./sq. ft., and at 50° C. the deposition rate is 0·0001 in. in two hours. At this rate very accurate control can be exercised over the amount of metal deposited, and for the majority of applications these conditions represent the best compromise of efficiency with economy. A faster rate of deposition can readily be achieved by using a solution containing 15 g. platinum per litre at 20 A./sq. ft., again at 50° C. In these conditions a thickness of 0·0001 in. will be deposited in 30 minutes.

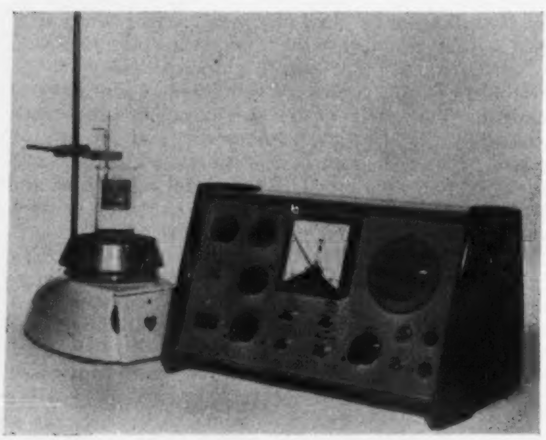
No agitation is required in using the bath. Where necessary, plating can be confined to specified areas by masking with a chlorinated rubber paint. Insoluble anodes are used in the process, and these should be of platinum. The anode surface area is not critical.

This new platinum bath gives bright, smooth deposits over a wide range of operating conditions. Deposits may readily be obtained up to 0·001 in. in thickness, and the bath gives consistent and reliable performance. The range of conditions within which satisfactory plates can be obtained makes the bath easy to work, and it does not deteriorate on standing.

Johnson, Matthey & Co., Ltd., 73–83 *Hatton Gardens, London, E.C.*1.

Controlled Cathode Electrolyser

The use of gravimetric electrolytic analysis has been limited in the past owing to the necessity of controlling the potential manually. This disadvantage has now been overcome in the Wadsworth controlled cathode analyser, and once an electrolysis is started the potential will not be allowed to rise above a preset value until the electrodeposition is complete. If a solution contains several metallic ions it is possible to plate them out separately by adjusting the E.M.F. so as not to exceed a predetermined value for each element in turn. The controlled cathode electrolyser is also ideal in polarography for carrying out preliminary separation of otherwise interfering ions. The apparatus has a maximum output of 10 A.



Southern Instruments, Ltd., Frimley Road, Camberley, Surrey.

Constant-Voltage Source

The Type 3 Reference Unit is a completely new solid-state D.C. reference source designed, developed and produced by George Kent, Ltd. for use with the company's range of electronic self-balancing recorders, indicators and controllers. A compact plug-in assembly operating directly from the normal A.C. mains supply, it provides an extremely stable, ripple-free output of 5·0 mA. at 5 V. for the slidewire of the instrument measuring circuit.

Two Zener-diode stages in cascade reduce the effects of normal supply variations by a factor of at least 200, while individual temperature compensation of each of these stages ensures that the output is substantially independent of changes in ambient temperature between 10° and 70° C. An inherent advantage is that the unit continues to operate with only slightly reduced accuracy if the supply voltage is drastically reduced, even to as little as 30% of its nominal value. The D.C. output is isolated from earth, and a specially screened and balanced mains transformer effectively isolates it from the mains supply. This feature is of great value in certain measuring circuits having a finite impedance to earth.

The exclusive use of solid-state components together with a very simple circuit configuration results in a rugged unit possessing a high degree of reliability. It is noteworthy that the only electrolytic capacitor employed is of the "super-quality" type, specially developed for applications where extremely long life is essential. Among the many advantages claimed to result from the use of the Type 3 Reference Unit are enhanced instrument performance; increased reliability and fewer components (no standard cell, synchronous converter etc.).

George Kent, Ltd., Luton, Beds.

Hydro-Pneumatic Cutting Machine

Salford Electrical Instruments, Ltd. (a subsidiary of The General Electric Co., Ltd.) announce the availability of a hydro-pneumatic machine designed for cutting semi-conductor crystals and slices and glass tubes for glass to copper seals. A machine of this type is already in operation at the G.E.C. Semi-conductor Division's factory at Hazel Grove, where it is used for slicing transistor germanium.

The machine is designed to cut at steplessly variable feed rates from 10 in./hr. to 1,000 in./hr. It is capable of automatic indexing for parallel cuts, the pitch being steplessly variable from 0 to 1 in. by micrometer adjustment. Repetitive accuracy of indexing is of the order of $\pm$ 0·001 in.

The cutter blade consists of a diamond impregnated or bonded wheel, and the high-speed spindle unit driving it may be designed for single or two speed operation and for single or multiple cutting discs varying from 6 in. to 4 in. diameter. The power available from the generator unit is 2 kW. The machine in use at Hazel Grove has a general purpose spindle unit of slender proportions in

order to clear work up to about 1¼ in. in height above the root of the cutting groove. This unit may be rotated with an eccentric mounting sleeve to increase or decrease the clearance between the cantilever housing and the work, total vertical adjustment being 1 in. Cutter widths vary from about 0·012 in. upwards.

The work may be attached to steel plates for mounting on either a 7 × 5 in. magnetic chuck, or on 8 × 8 in. plates which are clamped pneumatically. The work is waxed on to glass plates or attached by synthetic resins. The adjustment for pitch of cut indexing, the traversing rate of the work under the cutter, and the flow of coolant, are all arranged inside the cowl. Other operations are performed by controls mounted externally. The coolant used is Honilo fluid, which prevents sludge settling on the machine slides ; its vaporisation into the atmosphere is impossible while the Perspex cover is down.

The machine was designed at the Wembley Research Laboratories of the G.E.C.

Salford Electrical Instruments, Ltd., Silk Street, Salford.

Powder for Dip-Coating

THE Plastics Division of the Telegraph Construction and Maintenance Co., Ltd., has now introduced Telcovin "A" (PVC) powder as an addition to its range of thermoplastic powders for dip-coating, which already includes the well-established Telcothene (polythene, high or low density) and cellulose aceto-butyrate. Telcovin "A" provides a tough yet flexible finish with good resistance to inorganic chemicals and mineral oils, and enables powder dip-coating to be employed as an effective alternative to the current method of coating with PVC plastisols. Among the advantages of the powder, which can be used with all existing types of fluidising equipment, are speed of processing and elimination of the wastage and inconvenience caused by drips.

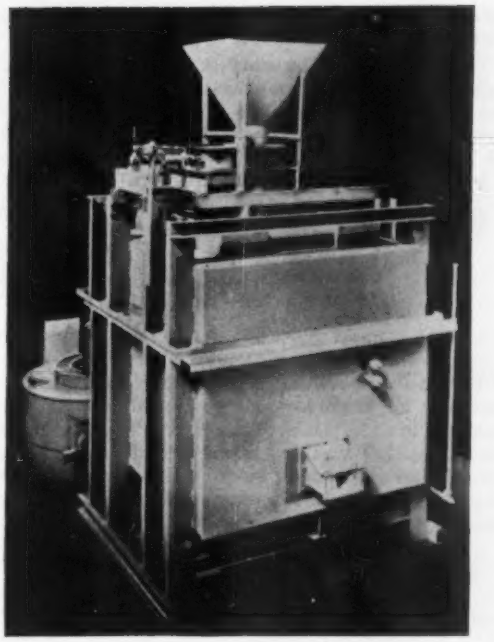
The Telegraph Construction and Maintenance Co., Ltd., Mercury House, Theobalds Road, London W.C.1.

Aluminium Melting and Holding Furnaces

A DRY hearth, aluminium melting furnace with a companion holding furnace, both of American design, are now being made in this country by the Electric Resistance Furnace Co., Ltd. The two furnaces form a central installation for melting up to 500 lb. an hour, and the metal can be ladled direct from the holding furnace or tapped off and delivered hot to other holding furnaces.

The aluminium scrap is charged into the furnace hopper where pre-heating begins. As it moves into the furnace it collects on and above a sloping, dry hearth of silicon carbide and is contained in a vertical cylindrical muffle, heated externally by silicon carbide elements. The molten metal is directed by the hearth through a covered trough where it runs out without overheating to be maintained in the holding furnace at the precise temperature required. To prevent oxidation, the aluminium is melted and held at temperature in an atmosphere of high purity, dry nitrogen. Oxide present in the scrap collects on the hearth and can be raked out through a plug door at the back. This door can also be used for inserting ingots.

The furnaces are ruggedly constructed and heavily heat insulated, and the heating elements are easily and



quickly replaced after their normal long life. Installations are supplied complete with temperature control gear and the furnaces can be arranged for operation on standard single or three-phase supplies. The melting furnace is rated at 100 kW., and the holding furnace has a capacity of 1,500 lb. and a rating of 20 kW.

Electric Resistance Furnace Co., Ltd., Netherby, Queens Road, Weybridge, Surrey.

Anti-Corrosion Paint

A NEW paint suitable for steel and weathered galvanised iron will shortly be available in the United Kingdom. It was developed in the United States by the Vita-Var Corporation of Newark, New Jersey, and was tested over a number of years in highly corrosive atmospheres before being marketed. Known as Vita-Var stainless steel paint No. 13448, it contains a mixture of stainless steel flake (18% Cr, 8% Ni) and several non-metallic pigments in a long oil alkyd resin vehicle. It is claimed that a series of tests, using the paint on transmission towers exposed to highly corrosive atmospheres, has shown it will afford protection to steel and iron structures for at least twelve years.

The paint is designed for use as a finishing coat and when first applied it is medium grey in colour with a semi-gloss finish. After about two years, it becomes lighter and brighter in appearance and closely resembles uncoated stainless steel. It may be applied to iron and steel by brush, spray or roller direct over old paint, provided it is in good condition. Bare metal should be primed with a Vita-Var corrosion resistant primer (No. 14142). In the case of galvanised iron, bare metal is coated with a red Vita-Var primer (No. 14399), which is supplied in two separate containers ; one of these holds red lead and vehicle, and the other dry metallic zinc dust. Before application the zinc dust is added to the red lead and mixed very thoroughly. It is not necessary to prime

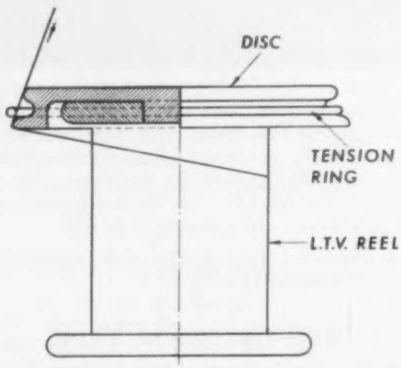
galvanised iron which has been previously painted, provided that the old coat is in good condition.

The stainless steel base of No. 13448 paint gives it very high protective qualities against corrosion. In addition, the paint has a very smooth finish which sheds dust and dirt. Annual maintenance costs of many types of plant are claimed to be reduced by 30% in tests conducted by the manufacturer.

Anthony Edwards & Associates, 57 Talgarth Road, London W.14.

High-Speed De-Reeling Device

A NEW high-speed de-reeling device known as a Biflaker, developed at the Huyton Quarry Winding Wires Division of British Insulated Callender's Cables, Ltd., consists of a precision engineered metal disc holding a metal ring designed to fit in the lip of the disc. The disc rests on the top of the L.T.V. (long traverse vertical) reel and the wire is paid off between the lip of the disc and the metal ring. By virtue of the weight of the ring, tension is applied to the wire during the de-reeling operation.



This is particularly important during the acceleration and deceleration periods which occur quite regularly during de-reeling operations. During deceleration the ring prevents the wire over-running, so that the wire on the reel never slackens off and falling turns do not occur. During acceleration there is never any initial slack to take up and, therefore, snarls are avoided. Thus the major hazard in flaking operations is removed quite simply and effectively.

With this device it is not necessary to restrain the wire as it winds from the reel, there being no tendency for the wire to balloon outwards from the reel. The wire can therefore always be on view and it is easy to estimate whether there is enough wire left on the reel at any one time to complete a winding. The Biflaker is designed for reels carrying up to 60 lb. of wire in the size range 0·0044–0·0124 in.

British Insulated Callender's Cables, Ltd.

Multi-Scanning Equipment

WEST INSTRUMENT, LTD., of Brighton, the temperature control instrument manufacturers, have begun production of multi-point scanning equipment designed for the continuous monitoring of temperatures at up to twelve positions in succession.

The temperature indicator consists of the standard West moving coil millivolt meter with a 5 in. scale, and sensing is by means of thermocouple or resistance bulb arrangement, according to the temperatures involved. The equipment can be arranged for two types of action. A single, maximum temperature can be pre-set on the scale and, if the temperature at any of the scanned points reaches this, scanning stops and an alarm or trip action to shut down the machinery comes into operation. On the second arrangement, two temperatures can be set on the scale. If the temperatures scanned reach the lower point, a relay is operated and this provides the necessary contact for an alarm ; then if the temperature reaches the second, a trip action is brought into operation. There is provision for manual operation of the scanning cycle and also a visual indication of the temperature indicated at any given moment.

The uni-selector methods of relaying between the thermocouple or resistance bulb and the indicator has been overlooked in favour of an enclosed mercury switch assembly which, it is believed, will give a longer and more reliable life. Each sensing element is switched to the indicator in turn through mercury switches operated by a cam driven from a synchronous electric motor. A keyed setting knob is provided which, once the setting has been made, can be withdrawn, so that unauthorised alteration of the set points is prevented.

West Instrument, Ltd., 52 Regent Street, Brighton, 1.

Packaged Lead Shielding Chambers

LEAD shielding chambers for handling radioactive materials are now available in a packaged form from Associated Lead Manufacturers, Ltd. Up to now it has been necessary for anyone wanting a shielding chamber to specify each structural component, but with the introduction of the new packaged chambers a buyer can start from minimum internal dimensions 26 in. wide, 24 in. high and 26 in. deep, and merely specify to Associated Lead the internal dimensions required. The complete chamber to the dimensions specified, and including two sphere units for remote handling equipment and a standard lead window-frame will be delivered in a case packed in sequence, which makes assembly on unpacking a straightforward operation.

There are three standard packaged chambers—all having 2 in. thick lead walls, the same minimum internal dimensions, two sphere units for remote handling equipment and a standard lead window-frame for observation. Type "A" chamber is made up of 2 in. thick solid wrought and precision machined bricks to A.E.R.E. specification and design with chevron mating surfaces. Type "B" chamber is made up of 2 in. thick solid wrought and precision machined bricks with curved mating surfaces. Type "C" chamber is made up of 2 in. extruded strip with serrated mating surfaces. By means of their unit construction "A" and "B" type chambers can be increased in width by units of 8 in. and in height and depth by units of 4 in. The "C" type chamber can be increased in all dimensions by units of 1 in.

Associated Lead Manufacturers, Ltd., 14 Finsbury Circus, London E.C.2.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
AUGUST, 1960 Vol. LXII, No. 370

Spectrophotometric Determination of Titanium in High-Temperature Alloys

By N. M. Silverstone and B. B. Bach, B.Sc., A.R.I.C.
Development and Research Department Laboratory, The Mond Nickel Co., Ltd.

A method is described for the determination of titanium in high-temperature alloys. The titanium is separated as hydroxide, and interference due to molybdenum, chromium and iron is eliminated. After dissolution of the hydroxide, hydrogen peroxide is added and the optical density of the solution is determined spectrophotometrically.

TITANIUM may be determined gravimetrically as the oxide, after precipitation and ignition of the hydroxide or cupferrate, or colorimetrically, as the peroxy-complex or cupferrate. These methods are all subject to interference from other constituents of high-temperature alloys or the colours are unstable. The method in general use is addition of hydrogen peroxide to an acid solution of the alloy and measurement of the optical density of the yellow-orange colour produced by the titanium and molybdenum, with subsequent correction for the molybdenum. This method pre-supposes accurate determination of the molybdenum and the preparation of correction calibrations. The work described below was carried out in response to requests for an alternative accurate method in which molybdenum did not interfere.

Experimental Procedure

According to Cheng,[1] it is possible, by using chloroform, and employing a suitably buffered solution of the alloy, to extract titanium as the cupferrate, and titanium is then determined by optical density measurements on the extract. Other constituents, which might form coloured cupferrates, are prevented from interfering by masking with ethylenediaminetetra-acetic acid. This method, as given by Cheng, was tested by the present authors and experiments were made also with symmetrical-tetrachlorethane, in place of chloroform, with a view to avoiding errors due to evaporation of the solvent. It was found, however, that in both cases the colour produced was unstable and intensified appreciably with time. In an attempt to produce a more stable colour, the cupferron was replaced by N-benzoyl phenylhydroxylamine, an analogue of cupferron which, according to Shome,[2] is stable. The colour produced with titanium was found to remain stable, but tests indicated that it would be difficult to achieve complete extraction.

The conditions required for the formation of the peroxy-complex of titanium are not critical and the colour is stable, showing a peak absorption at 410 mμ. At this wavelength, however, there is an appreciable optical density from the yellow peroxy-complex of molybdenum. Titanium may be separated, as the hydroxide, from many of the major constituents of high-temperature alloys, including molybdenum, by the addition of ammonium hydroxide to a solution of the alloy. The precipitate would also contain aluminium, iron, chromium and zirconium, as hydroxides. It would be possible to determine titanium in this mixture, but the presence of large amounts of chromium would lead to difficulties. This difficulty can be overcome by fuming the alloy solution with perchloric acid, thus converting chromium to chromate, which does not give a precipitate with ammonium hydroxide. In the presence of perchloric acid, however, ammonium hydroxide forms with nickel a sparingly soluble compound, which is believed to be nickel ammonium perchlorate.[3] The use of ammonium hydroxide is therefore not feasible. Pyridine, under the same conditions, does not form a similar, insoluble compound, but will precipitate titanium, aluminium, iron and zirconium as hydroxides: it was, therefore, chosen in place of ammonium hydroxide. It was found that the addition of about 1 g. of ammonium chloride and a small amount of paper-pulp to the solution, before adding the pyridine, aided subsequent filtration.

Examination of the solution formed by dissolving the mixed hydroxides in dilute sulphuric acid showed the presence of a small amount of chromate. This would interfere with the titanium determination because, even if a compensating blank were used, the chromium would not be in the same form in both the blank and measuring solutions: in the former it would be present as the yellow chromate and in the latter, in the presence of hydrogen peroxide, in the greenish chromic form.

The chromium is probably precipitated as a basic aluminium chromate, which should be soluble in sodium hydroxide solution, and tests confirmed that the chromium was indeed removed by washing the precipitate with hot dilute sodium hydroxide solution but, in addition, a portion of the titanium hydroxide was removed, resulting in low titanium results. According to Jewsbury and Osborn,[4] thioglycollic acid will form complexes with Cr^{III} and Fe^{III} and prevent their precipitation as hydroxides in alkaline solutions. Tests confirmed this find, even when the chromium was originally present as Cr^{VI}: probably the thioglycollic acid reduced the Cr^{VI} to

TABLE I.—TITANIUM RECOVERY

Titanium Added (%)	Titanium Found (%)	
	A	B
0·50	0·48	0·50
1·00	1·00	1·00
1·50	1·50	1·51
2·00	2·00	2·00
2·50	2·51	2·49

A Pure titanium solution + 10 mg. aluminium per sample. (The aluminium acts as a collector for the titanium hydroxide).
B Pure titanium solution + synthetic high temperature alloy. (Approximate composition—Co 20%, Cr 10%, Mo 5%, Al 5%, Fe 0·5%, Ni bal.).

Cr^{III} and then formed the complex. It was found that under similar conditions interference from vanadium, which would be precipitated as a basic vanadate, would also be prevented.

Recommended Procedure

Reagents

Wherever possible, reagents should be of AnalaR or equivalent grade.

Perchloric Acid (sp. gr. 1·54)

Ammonium Chloride

Pyridine

Hydrochloric Acid (50%)—Dilute 500 ml. hydrochloric acid (sp. gr. 1·16–1·18) to 1 litre with water.

Thioglycollic Acid (20%)—Dilute 20 ml. of reagent to 100 ml. with water.

Ammonium Hydroxide (sp. gr. 0·880).

Sulphuric Acid (25%)—Add 250 ml. sulphuric acid (sp. gr. 1·84) to 500 ml. water, cool, and dilute to 1 litre with water.

Hydrogen Peroxide (100 vol.).

Wash Solution "A"—Dissolve 10 g. ammonium chloride in 1 litre of water.

Wash Solution "B"—Dilute 20 ml. thioglycollic acid reagent and 50 ml. ammonium hydroxide (sp. gr. 0·880) to 1 litre with water.

Standard Titanium Solution—Dissolve 0·2000 g. pure titanium wire under an air condenser by adding 50 ml. sulphuric acid (sp. gr. 1·84) and spotting in water until reaction commences. Keep hot until all the metal has dissolved, cool, and dilute to exactly 200 ml. with water. 1 ml. ≡ 0·5% titanium on a 0·2 g. sample.

Method

Transfer 0·2 g. of sample into a 250 ml. tall-form beaker, add 5 ml. of perchloric acid, cover with a watch-glass and heat to complete dissolution. Carefully evaporate to fumes and fume gently for 2–3 minutes to oxidise the chromium. Cool, wash down, and adjust the volume to 100 ml. with hot water. Add 1 g. of ammonium chloride, a little paper-pulp and 8 ml. of pyridine. Bring to the boil, allow the precipitate to settle and filter, using a gravity paper-pulp pad and washing well with hot, wash solution " A ." Dissolve the precipitate, through the pad, into the original beaker, using boiling hydrochloric acid (50%) and washing with hot water.

To the solution add a little paper-pulp, 10 ml. of thioglycollic acid (20%), and make ammoniacal, adding 2–3 ml. in excess. Bring to the boil, allow the precipitate to settle, filter through a gravity paper-pulp pad, washing with hot water solution " B."

Wash the precipitate and beaker once with hot water.

TABLE II.—DETERMINATION OF TITANIUM IN NIMONIC 100*†

Sample	Titanium (%)		
	Determined Values	Average	Standard Deviation
1	1·26, 1·26, 1·25, 1·25, 1·23.	1·25	±0·01
2	1·35, 1·34, 1·34, 1·34, 1·34.	1·34	±0·005
3	1·55, 1·53, 1·52, 1·51, 1·50.	1·53	±0·02
4	1·72, 1·72, 1·71, 1·71, 1·69.	1·71	±0·01
5	1·90, 1·90, 1·89, 1·89, 1·87.	1·89	±0·01

* Nimonic 100† composition: C 0·30% max., Ti 1·0–2·0%, Cr 10–12%, Al 4·0–6·0%, Mo 4·5–5·5%, Si 0·5% max., Fe 2·0% max., Co 18–22%, Ni bal.

† Registered trade mark.

Dissolve the precipitate with 40 ml. boiling sulphuric acid (25%), contained in the original beaker, into a 100 ml. volumetric flask, washing several times with small volumes of hot water. Cool to room temperature, add 2 ml. of hydrogen peroxide, dilute to volume with water and mix thoroughly.

Determine the optical density of the coloured solution against that of a blank solution (consisting of 40 ml. sulphuric acid (25%) and 2 ml. hydrogen peroxide diluted to 100 ml.) set to an optical density of 0. Preferably a Uvispek spectrophotometer is employed, using 2 cm. glass cells and a slit width of 0·1 mm. Measurement should be made at a wavelength of 410 mμ.

Calculation of Results

The optical density is converted to percentage titanium by means of the prepared calibration graph.

Calibration

Into a series of 100 ml. volumetric flasks pipette 1·0, 2·0, 3·0, 4·0 and 5·0 ml. of standard titanium solution, equivalent, respectively, to 0·50%, 1·00%, 1·5%, 2·00% and 2·50% of titanium. Add 40 ml. sulphuric acid (25%), 2 ml. hydrogen peroxide, dilute to volume with water and mix thoroughly. Measure the optical density of each solution as above and plot a graph of optical density against percent titanium.

Results

The method described above was checked on a standard titanium solution. Results obtained showed that the recovery from both pure solutions and solutions of a synthetic high-temperature alloy was very satisfactory and that no interference was experienced from molybdenum and other metals present in the solution (see Table I). The titanium content of a number of samples was determined, and the results (see Table II) demonstrate that the method is accurate and that it gives good reproducibility over the range 1–2% titanium.

Acknowledgment

The authors are indebted to the Mond Nickel Co. Ltd., for permission to publish this paper.

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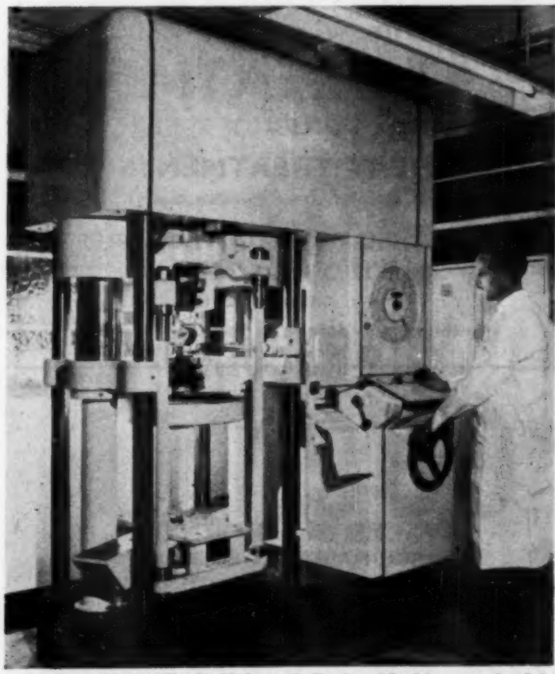

A Denison Model T42B Universal Testing Machine at the laboratories of John Holroyd & Co. Ltd., Holfos Works, Rochdale. Photograph shows the Patent Mechanical Extensometer being used.

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